Cranfield University

Juliette BUTCHER

Industry-Academia Research Collaboration; characterising structure, process & attitudes in support of best practice

School of Water Sciences

PhD Thesis

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Ph. D. Thesis

Academic year 2004-2005

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Industry-Academia Research Collaboration; characterising structure, process & attitudes in support of best practice

Supervisor: Dr P JEFFREY

March 2005

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Abstract

Industry-academia collaborative research has become a subject of increasing interest in recent years to academics, industrialists and policymakers due to greater awareness of the importance of such links for innovation and the knowledge-based economy. However, such collaborations are not always successful for reasons which are poorly researched. The main objective of this thesis is to identify the main factors that impede or enhance successful research collaboration. The research agenda is guided by a review of the current literature which indicates that the effectiveness of industry-academia collaborative research depends to some extent on the following factors: (i) the motivations/objectives for collaborative research, (ii) the modes of communication between collaborative partners, and (iii) the management of the collaborative process. The influence of each of these three factors on collaboration effectiveness is investigated using a conceptual model and two pieces of complementary fieldwork.

The conceptual model illustrates the relationship between the three factors and the structure of collaboration, the collaborative process and the attitudes of collaborative participants. The fieldwork activities, which provide data on individual perceptions of industry-academia collaborative research experience, comprise an interview survey of collaborative research facilitators, and a questionnaire survey of students working on projects jointly supervised by academics and industrialists. Findings from these two activities are analysed in terms of their contribution to the existing literature on industry-academia collaboration and their conformity with the conceptual model. The perspectives of the research facilitators are also directly compared with those of the students. The results support current awareness in the literature that industry-academia collaborations are difficult to analyse and manage because of their diverse structures, their dynamic nature and the variety of factors that influence their effectiveness. Whilst the research findings do provide some indication of why collaborations succeed or fail and how they can best be managed, the fact that no two collaborations are the same in terms of motivations, objectives, structure, process, outcomes, type of participants, etc., precludes prescriptive generalisations. Suggestions for best practice include adopting an adaptable management structure and using a 'relationship management' approach for long term collaborative relationships.

Acknowledgements

This thesis, quite simply, could not have been written without the supervision, guidance and support of my supervisor Paul Jeffrey. Many thanks for your support and encouragement during the course of this study.

This work would have not been possible without the assistance of Richard Stuetz. I am indebted to you for your help. The financial support of EPSRC and Cranfield University is also acknowledged.

Most comfort and support was given by Wilfrid Bourgeois who constantly encouraged me and kept me sane. I am extremely grateful for your care and patience. Thanks must also go to his parents, Gerard and Jacqueline, and his brother, Gwendal, for their care and affection.

Last but foremost I would like to express all my gratitude and my love to my parents and my brother, who have encouraged and supported me during my many years of study. Thanks Mum, Dad and James.

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1. Introduction

The effectiveness of industry-academia research collaboration has become a subject of growing interest in recent years to academics, industry leaders and policymakers both in the United Kingdom and internationally, because it is now recognised that such links are extremely valuable for innovation and the knowledge based economy. As a result of increasing international competition and rapid technological change, governments in many countries are actively encouraging collaboration between industry and universities to improve innovation efficiency and therefore enhance wealth creation (Barnes *et al.*, 2002). Academics are also actively seeking support (mainly financial) from industry, and companies in a wide variety of sectors are looking for new ideas or knowledge from universities to sustain future profitability. This has led to a significant increase in different modes of collaboration between industry and academia over the past decade including collaboration on research. Companies and universities are however not natural partners; principally as a result of their different organisational cultures and missions (Lambert, 2003). This introductory chapter provides a general background to the topic, defends the need for research in this area, and provides a guide to the structure of the thesis.

1.1 Collaboration & innovation

> *'In the real world innovation takes place among groups of people, in diverse situations, with divergent experiences and possible mutually incompatible desires and beliefs.'*
>
> (Nightingale, 1998; cited in Stewart, 1999)

Collaboration helps generate new knowledge and ideas and is therefore a valuable element amongst many for innovation. Knowledge generation and transfer are non-linear paths of problem identification and analysis, communication, interaction, and learning by and among the various partners in the innovation process (Scheutze, 2001). Also as Stewart (1999) points out, it is not just new knowledge that contributes to innovation; recombined and rediscovered knowledge also plays a role. It is people, and the experience and expertise that they bring with them, that are one of the most effective ways of transferring knowledge. A whole range of different scientific disciplines needs to be brought together in order to make technological breakthroughs (Lambert, 2003). Science-based innovation increasingly requires multidisciplinarity and builds on people based interactions (OECD, 2002). Recent studies on industry-science relations have shown that universities as well as public research centres are important as co-operation partners in innovation projects (Polt *et al.*, 2001). Most major technological advances and innovations originate from interactions between industry and the scientific community (Hameri, 1996).

Research supports innovation through a number of channels including: increasing the stock of useful knowledge, the supply of skilled graduates, the creation of new instrumentation and methods, the development of new scientific networks, the enhancement of technological problem solving capacity, the generation of new firms and the provision of social knowledge (Salter *et al.*, 2000; Scott *et al.*, 2001). In their study of industry-academia interactions in three fields of advanced technology, Senker *et al.* (1998) found that the greatest contribution of academia to innovation takes the form of indirect and intangible flows of ideas, knowledge and expert assistance. Thus, increasing the number of (informal) communication channels (and thus knowledge flows) between academia and industry is a key means of enhancing academia's contribution to innovation.

Industry and science linkages and the diffusion of knowledge within national innovation systems are therefore emerging as a primary focus for innovation policy in many countries. The Organisation for Economic Co-operation and Development (OECD, 2002) quote:

> *'Today, the performance of an innovation system increasingly depends on the intensity and effectiveness of the interactions between the main actors involved in the generation and diffusion of knowledge.'*
>
> (OECD, 2002; p. 15)

From the early 1990s onwards, the UK government set up a large number of policy initiatives with the aim of enhancing collaboration between industrialists and academics to help contribute to innovation and consequently to national economic growth (Stewart, 1999; OECD, 2002). The government's White Paper on the UK's science and technology policy *'Realising our potential'* (HMSO, 1993) led to significant emphasis on policies designed to encourage closer contact and interactions between academia and industry. Examples of current schemes initiated by the UK government to promote collaboration between industry and universities include LINK, Knowledge Transfer partnerships, the Co-operative Awards in Science and Engineering (CASE) and the Faraday Partnerships (see Chapter 2.5 for more information).

1.2 The need for research

While the university-industry interface might be a key factor in promoting innovation, the complex and varied nature of that interface needs to be understood and explored (Rappert *et al.*, 1999). Such evaluative enquiry is, however, far from straightforward. According to the OECD (2002), governments generally lack information and tools to monitor industry-science relationships and evaluate their efficiency. A variety of barriers and constraints may adversely affect industry-academia relationships; many as a result of differences in the purposes, cultures, procedures, value systems and incentives of universities and companies, making communication and collaboration challenging. There is now a plethora of literature on the subject of university-industry research partnerships (see Chapter 2) but only a few studies have explored this topic in great depth, in particular the analysis of factors that impede or enhance successful collaboration through the use of both qualitative and quantitative methods.

Many studies have also focused on technology transfer, the commercialisation of research and the mechanisms of this process. There is a lack of research on industry-academia collaborative research which involves academic researchers and company employees working together on shared problems or projects. According to Lambert (2003), industry-academia collaborative research is one of the most effective forms of knowledge transfer as by working together on shared problems, the participants develop mutual trust and share information and are therefore more likely to make significant breakthroughs. There is therefore a recognised need for in-depth research on industry-academia collaborative research and the factors that influence their effectiveness.

This thesis seeks to identify and characterise the relative impact of those factors which may influence the success of industry-academia collaborative research via the perspectives of individuals involved in such relationships. The research is based on the argument derived from a review of the current literature on industry-academia collaboration (Chapter 2) that the effectiveness of industry-academia collaborative research depends to a degree on three key elements (see Section 4.1, Chapter 4):

i) 'Motivations & Objectives' for collaborative research;
ii) 'Communication' between collaborative partners;
iii) 'Management' of collaborative processes.

To help investigate the influence of each of the key elements listed above on the effectiveness of collaborative research, several research questions (one primary question & three secondary questions) were established (see Chapter 4) to help guide the research activities as follows:

P1 *'What is the nature and extent of influence of barriers to effective industry-academia research collaboration in terms of (i) motivations and objectives, (ii) communication, and (iii) management?'*

S1 *Are there differences in individuals' motivations for or perspectives towards collaboration in different sectors and how do these differences influence the effectiveness of collaboration?*

S2 *Do individuals' disciplinary backgrounds influence communication and knowledge transfer between collaborators?*

S3 *What are appropriate managerial or organisational strategies for effective industry-academia research collaboration?*

A conceptual model is also developed (in Chapter 4) to illustrate the relationship between the three key elements and the structure of collaboration, the collaborative process and the attitudes of collaborative participants. Answering the research questions enables us to:

i) Identify ways of balancing the competing objectives and sources of conflict within collaborating teams;
ii) Identify effective communication formats;
iii) Provide guidance on the management of industry-academia research collaborations.

The research focuses on industry-academia collaborative research in the UK only because industry-science linkages and incentive schemes differ between countries due to variances in political, economical, historical, cultural, and social contexts. Thus approaches or best practice identified in one country may not be applicable to other countries (Polt *et al.*, 2001).

1.3 Meanings of collaboration effectiveness & success

Throughout this thesis, the terms 'effectiveness' and 'success' both have the same meaning. There is however no universal definition of success or effectiveness in collaboration because:

- Different participants involved in collaboration (industrialists, academics, government, etc.) have different perceptions or definitions of collaboration success (which can be subjective or objective, or both);
- The definitions of success vary by type of collaborative relationship, each of which has different objectives, procedures and outcomes;
- The definitions of success also depend on the stage of the collaborative process being observed.

Therefore, as Bozeman & Boardman (2001) point out: '*a one dimensional definition of collaboration effectiveness is unrealistic*'. A workshop on industry-academia research collaborations run by the National Academy of Science (US) provided several indicators of success that are viewed as common by all participants involved in collaborative research (NAS, 1997, p.13):

- project milestones are achieved;
- frequent communication between partners occurs;
- the number of quality publications and student theses resulting from collaborative research is comparable to other productive research areas;
- the number and quality of ideas resulting in follow-up activity shows a mutually stimulating influence among the partners;
- intellectual property (e.g. no. of patents/copyrights applied for or granted) is generated;
- the number and quality of graduate students or post-doctoral fellows hired by industrial partners are increased;
- continuity of the relationship extends beyond the initial projects; and
- the fiscal status of the partnering company improves.

Some of the indicators listed above are identified in the research findings described in Chapters 5 and 6 (e.g. frequent communication and continuity of the relationship).

1.4 The Lambert review

In November 2002, HM Treasury, the Department for Education and Skills and the Department for Trade and Industry commissioned a review of business-university collaboration in the UK. 'The Lambert Review' was published in December 2003 during the latter stages of the research described in this thesis (therefore it is only referred to in the discussion chapter). It includes a series of recommendations across a wide range of issues aimed at *'smoothing out the bumps' (p.10)* which can hinder industry-academia collaboration. The findings from the Lambert review do not substantively affect the findings from the research described in this thesis but are a useful complementary knowledge set. The review mainly focuses on the following issues: business demand for collaborating with universities, the national, regional and local economic impacts of industry-academia interactions, the skills required by businesses from universities, and the present governance of universities. These issues are not explicitly addressed by the research reported in this thesis. It does not consider ways of encouraging industry-academia collaboration (e.g. increase awareness of collaborative schemes or identify suitable initiation channels) nor does it consider the contribution of collaboration to the national or regional economy. Instead the research is concerned with how the effectiveness of industry-academia collaboration can be improved.

The recommendations from the Lambert review pose a challenge to all stakeholders involved in industry-academia collaboration and there are likely to be shifts in the policy horizon arising from this review. The information to support the review came from a number of universities, companies, regional authorities, policy makers; mainly from the UK, but also from Europe, the US, Japan and Australia. Lambert concluded that although there is a lot of good collaborative work in progress, more needs to be done.

1.5 Thesis structure

Figure 1 illustrates the logical structure of the thesis in terms of substantive relationships between chapters. The contents of subsequent chapters are summarised as follows:

- **Chapter 2** presents a literature review, providing background information to the research in this thesis. In the review, current literature on industry-academia collaborative research is explored from several aspects including: the variety of mechanisms developed to assist different collaboration needs, the motivations of the different parties to collaborate, the various incentive schemes that support such relationships, the ways of managing and evaluating collaborative endeavours, and the range of factors (barriers) that may affect collaboration.

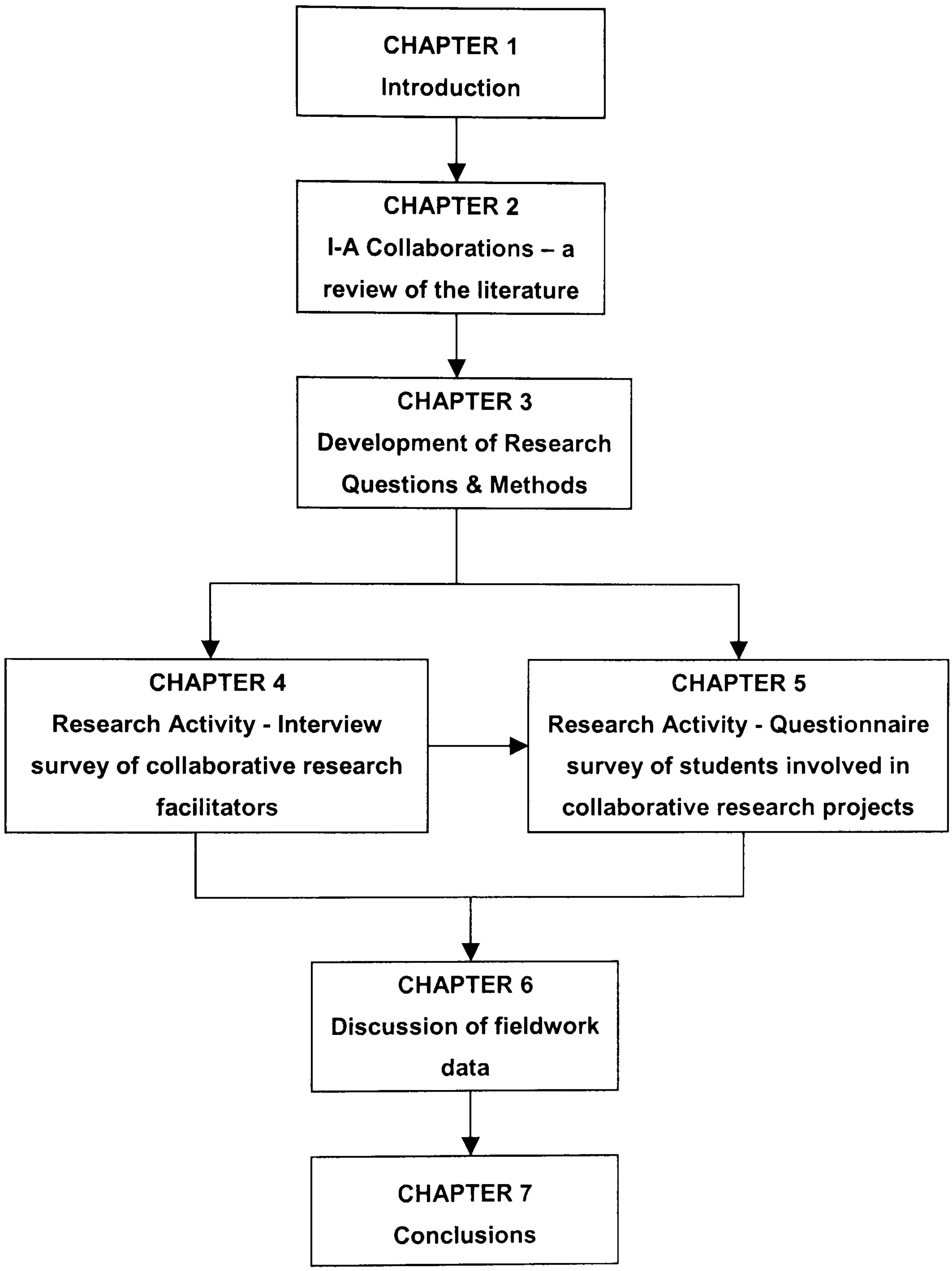

Figure 1.1: Structure of thesis

- Key issues and 'gaps' in knowledge emergent from the research background reported in Chapter 2 are integrated in **Chapter 3** where the research questions which underpin the study carried out in this thesis are introduced. This chapter also looks at the development of the conceptual model used to illustrate the importance of the three key elements (motivations/objectives, communication & management) to industry-academia collaboration. The last section of this chapter looks at how an agenda for the research activities reported in Chapters 4 and 5 was developed to help answer the research questions.
- The next two chapters present the core research activities carried out to obtain and analyse individual reflections and perceptions of the experience of industry-academia collaborative research. In **Chapter 4,** the activities and results of interviews carried out with industry-academia collaborative research facilitators are described. In **Chapter 5,** the activities and results of a questionnaire survey of students working on projects jointly supervised by academics and industrialists are presented.
- The findings of the two core research activities described in Chapters 4 and 5 are drawn together and discussed in **Chapter 6**. This chapter includes an assessment of how the survey findings inform or support the current literature on industry-academia collaborative research, a comparative analysis of the perspectives of the collaborative research facilitators and the students, and an inquest into how the research results have contributed to the conceptual model described in Chapter 3.
- Finally the conclusions of the study are presented in **Chapter 7** by looking at how the thesis has contributed to our understanding of the factors that influence the effectiveness of industry-academia collaborative research. First, the research questions that guided the research activities are responded to directly using the knowledge gained from the research findings. This is followed by a reflective evaluation of the research procedure and the conceptual model developed in this thesis. The final section of the chapter concludes the thesis by looking at the implications of the research findings for the planning and management of industry-academia collaborative research, additional issues found in the research

findings to be of significance to our understanding of industry-academia collaborative research and areas for future research.

1.6 Definitions

Definitions adopted by researchers working in the field of Science, Society and Technology or Science Policy Studies are often not uniform. Some key terms are defined here to establish their meaning in this thesis:

Collaborative research

The definition from the Association for University Research and Industry Links (AURIL, 1997, p. 12) for collaborative research is adopted. In collaborative research:

- 'the research goals are defined by all the partners';
- 'all the partners contribute to the goals of the research by undertaking specific parts of the research programme';
- 'all the partners share interim results, collectively review problems as they arise and agree any changes to the project goals or research methods';
- 'all the partners contribute financially to the costs of the research. The project may also be part-funded via public schemes operated by the UK Government or the European Commission'.

The collaborative research schemes explored in this thesis, including the student projects described in Chapter 6 (EngD & CASE) are characterised by the definitions given above.

Academia

Academia is any institution in the higher education sector.

Industry

Industry is any other organisation, public or private, which may benefit from collaboration with academia, including government departments and charities.

2. Industry-Academia Collaborations - a review of the literature

The study of industry-academia collaboration incorporates a range of aspects including: the diversity of mechanisms (formal or informal) developed to assist different needs, the motivations of the different parties for collaboration, the various incentive or promotion schemes that support such relationships, and most important of all, the range of factors that may adversely influence collaboration (barriers). The aim of this chapter is therefore to present a general review of the literature on university-industry research collaboration in order to improve our understanding of this topic and subsequently support the development of a framework for the research presented in Chapters 3 to 5. Figure 2.1 shows those aspects of university-industry research collaboration that will be covered in this chapter.

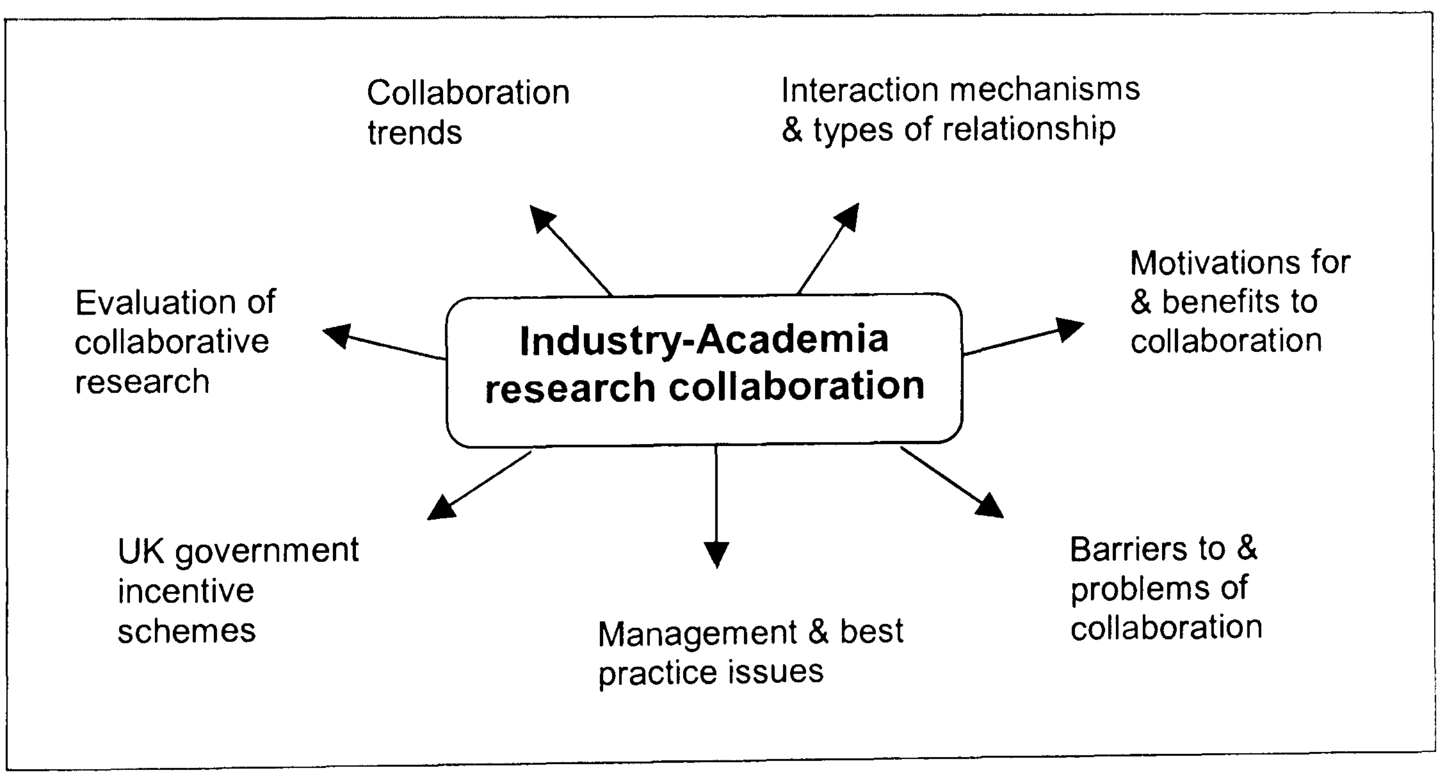

Figure 2.1: Elements of industry-academia collaboration to be reviewed in Chapter 2

It will not be possible to review all elements in great detail and the set of particular interests outlined in Chapter 1 provide a specific agenda to address. There are a number of challenges to a review of the literature on this topic, including the fact that the relevant studies cover a wide range of academic fields including economics, politics, sociology, technology studies and management. This results in an abundance of terminology and subsequent difficulties in both understanding and interpreting the theories or findings of these studies. There are also variations in the nature of industry-academia relationships and incentive schemes between different countries due to different political, economical, historical, cultural, and social contexts so successful approaches or best practice in one country (or even one region) may not be applicable to other countries (Polt *et al.*, 2001). This contribution therefore pays particular attention to studies carried out on industry-science linkages in the UK and the section on incentive schemes will mainly focus on schemes set up by the UK government. The issues or 'gaps' in knowledge emergent from the material presented in this chapter (and which will be directly addressed in the research agenda in Chapter 3) will be described in the concluding paragraph of each of the following sub-sections.

2.1 Collaboration trends

This section explores industry-academia research collaboration from a historical aspect by describing how such collaborations have changed over time, both the extent of and in terms of disciplinary structure (institutional and subject). It also looks at the factors that have influenced these trends. According to Calvert and Patel (2002), timely and accurate information on the nature and extent of interactions between universities and industry, and how it varies across discipline, institution type, sector, and over time is important for effective policy making on industry-academic relationships.

Although the roots of industry-academia links can be traced back to the late nineteenth century in the UK (Howells *et al.* 1998), it is believed that many new forms of collaboration and communication between universities and industry came about during the 1980s as a result of the recession (OECD, 1984). Declining productivity levels led to structural change in many industrial sectors which involved the need to transform the basis of productive activities by introducing new technology, processes and techniques. This initiated renewed interest on the part of many industrial firms, large and small, in the research activities of universities, which in turn resulted in the establishment of new links between industry and academia. At the same time there was a decline in public resources which affected many universities and many found it necessary to augment traditional government sourced finance with income from industry to be able to maintain a viable research presence. As a result, industry-academia relations underwent major shifts during this period, as traditional methods of working or funding were found insufficient.

More recently, the changing importance and nature of knowledge in modern society as well as government policies that aim to promote global competitiveness in markets via innovation have led to a marked shift in the perception of the university's role, particularly in industrialised countries. As a result many forms of collaboration including co-operative research, public-private partnerships, and international or domestic strategic alliances show signs of increasing (OECD, 2002). This has been demonstrated in key studies by Gibbons *et al.* (1994) and Etzkowitz and Leydesdorff (1997) which both show the development of new types of relationships in the knowledge production process. Gibbons *et al.* describe a transition in knowledge production processes from what they term 'Mode 1' where knowledge is created within a disciplinary context to 'Mode 2' where knowledge is generated in a wider transdisciplinary social and economic context:

> *'The familiar discipline-based, internally driven, individually dominated structures that currently dominate the universities and the public sector laboratories are yielding to practically oriented, transdisciplinary, network-dominated, flexible structures that are characteristic of the mode of organisation of science and technology in the most advanced sectors'*
> (Gibbons *et al.*, 1994)

Table 2.1 outlines the difference between Mode 1 and Mode 2 knowledge production as summarised by Tranfield (2002). Mode 1 is referred to as a 'traditional' form of knowledge production driven by the academic community where theory is developed and then applications of the new theory are considered, hence there often is limited interaction with potential end users. In

Mode 2 knowledge transfer is no longer considered as a linear process from origin to application, i.e. both theory building and application occurs together in the knowledge production process. Here a diverse range of practitioners are involved in the process, from setting up the research agenda through to the production of outputs.

Table 2.1: Mode 1 & Mode 2 Knowledge (summarised by Tranfield, 2002)

Mode 1	*Mode 2*
▪ problems being set & solved by the academic community, ▪ using a disciplinary staff base patrolled by elite academic gate keepers called professors, ▪ based in institutionalised research organisations such as universities, ▪ with dissemination dislocated from knowledge production activities and usually occurring down-stream.	▪ problems being set and solved 'in the context of application', ▪ using a trans-disciplinary staff base often working as collaborative consortia and, ▪ including not only academics but also practitioners, policy makers, and consultants

Multidisciplinary and multi-institutional working allows greater creativity and innovation among researchers therefore the emphasis is on encouraging transdisciplinary mode 2 type learning and knowledge production rather than single discipline mode 1 learning (Gibbons *et al.*, 1994). Appendix 2A shows the results of a study carried out to explore collaboration trends in an applied field of research over time through the use of co-authored papers. This study showed increasing collaboration between departments, disciplines (subject fields) and countries in recent years. These trends in inter-institutional, cross-disciplinary and international collaboration demonstrate the transition from mode 1 to mode 2 knowledge production, i.e. transdisciplinarity has become the 'norm'.

Gibbons *et al.*'s model poses challenges to the way industry-academia relationships work and are managed. New modes of knowledge creation and dissemination indicates the need for new ways of evaluating and managing such flows to be effective, i.e. we are not dealing with unidirectional but with multi-directional knowledge flows. New approaches to supporting, funding, monitoring, and assessing such relationships are needed. The theories of Gibbons *et al.* have also stimulated considerable interest in and re-evaluation of the ways in which research in specific academic fields work. There is belief that some research fields (especially those of an applied nature) should use Gibbons *et al.*'s ideas concerning mode 2 knowledge production to help them be relevant to practice. This is demonstrated in the paper by Tranfield (2002) where he argues that a multi-disciplinary, multi-national and multi-institutional approach should be implemented in the field of 'management research' to help it be relevant to practice. Becher & Trowler (2001) state that universities are restrained by their disciplinary structures (mode 1) and need to change to adapt to this new environment to be relevant and effective in mode 2 knowledge production. For universities to be relevant in such knowledge production, academics need to work in collaborative teams which cut across disciplinary and/or institutional boundaries (Newell & Swan, 2000).

In their evolutionary 'Triple Helix' model of academia-industry-government relations and roles, Etzkowitz and Leydesdorff (1997) demonstrate the importance of successful interactions between the various players for the development of the knowledge based economy. This model is a normative or policy guide for national systems of innovation providing a prescriptive answer to the problem of competition and knowledge generation. Etzkowitz and Leydesdorff argue that cooperation between universities, industry and government is a key component of any national or multinational innovation strategy and that innovation is more likely to develop holistically rather than in a linear fashion. The triple helix model is however also an empirical description of what is happening in various parts of the industrialised world. According to Etzkowitz & Leydesdorff, this model demonstrates not only changes in the relationships between all three parties but also internal transformation within the different organisations.

In conclusion, this section has demonstrated the importance of industry-academia relationships for the knowledge based economy and highlighted some of the factors influencing the increasing levels of inter-organisational and inter-disciplinary collaboration in recent years. There is therefore, a need for research investigating the factors that may either impede or help enhance successful collaboration between different types of participants (individual & organisation). For example, do the disciplinary backgrounds (subject, educational or professional) of the participants from different organisations influence successful collaboration? Are current management practices appropriate for managing inter-organisational or inter-disciplinary collaborations? Answering such research questions would help us find appropriate mechanisms for successful interaction between different fields of research and different types of organisations.

2.2 Interaction mechanisms & types of relationship

There are various mechanisms via which information and know-how are transferred between universities and industry, the form of which is influenced by the motivations of the players involved and the objective of the relationship. The objective of interaction can take many forms, for example, product and/or process development and improvement, personnel training or use of an available service, etc. These different types of collaboration vary considerably in terms of the extent to which industry and universities define the research goals, contribute the requisite resources, and share in the outcomes and any associated benefits (AURIL, 1997). A number of terms have been used to characterise or classify university-industry relationships in the literature. These include 'formal' and 'informal', 'premeditated' and 'unplanned', 'direct' and 'indirect'. Scott *et al.* (2001) identified four main types of communication channel from the literature which characterise university-industry relationships:

- Codification or artefacts: channels that involve the diffusion of ideas, information, and designs by codification, e.g. publications, patents, prototypes.
- Cooperation: channels that involve cooperation between universities and industry, e.g. joint ventures (collaborative research), personnel exchanges.
- Contacts: channels that involve interactions between public researchers and their counterparts in companies, e.g. meetings or conferences,

informal interactions, science parks, studentships, teaching, funded networks.

- Contracts: channels that are based on formal contracts between public sector research organisations and companies, e.g. licences, contract research, consulting, product testing, business support.

All these types of channel are characterised by an exchange of knowledge among the participants and companies see many of them as important mechanisms for getting value from publicly funded research. The majority of industry-science relations have been found to take place through informal and indirect channels (OECD, 2002). Regardless of economic sector or industry, the majority of 'formal' industry-university partnerships are of the *research partnership* type, which mainly involve applied research and where funding from industry is received in exchange for "intellectual horsepower" in the form of research services and technology (Koch *et al.*, 2000). The wide range of types of interaction often makes it hard for potential collaborators to identify which type is appropriate for their particular needs (Stewart, 1999). In their guide, the Association for University Research and Industry Links (AURIL, 1997) provide a simple classification of the various types of relationship and their advantages and disadvantages. More recently, Carayol (2003) built a detailed and complex typology exhibiting five different types of collaboration by analysing information obtained mainly by interviews on the characteristics and structures of 46 different collaborations within two science-based sectors in 5 different countries.

Collaboration and communication between industry and universities usually begin informally and are characterised by person-to-person contacts and then, from this base, gradually become more formal leading eventually to contracts and/or other forms of linkage (OECD, 1984). Personal contacts have been shown to be the main initiation channel for many forms of industry-academia collaboration in recent studies (e.g. Howells *et al.*, 1998). A common first 'formal' contact between a university and a company is contract research which academics see as important not only because it generates financial income but also because if the research progresses satisfactorily there is potential for a longer term collaborative relationship (Stewart, 1999). It is however widely acknowledged in the literature that the most important types of interaction are the public and personal channels such as informal relations and collaborative research, as opposed to other means like formal contracts (e.g. Senker *et al.* 1998, Rappert *et al.*, 1999; Meyer-Krahmer & Schmoch, 1998). The main reason for this is that communication channels such as informal contacts and collaborative research involve a bi-directional exchange of knowledge, whereas those such as contract research are primarily a one-way knowledge export from universities to industry.

Networks of industrialists and academics which either focus on a particular scientific technique, or are geographically based with a view to identifying common problems and exploring possible cross-sectoral or cross-disciplinary solutions to these problems, are important channels for the flow of ideas and information. They give companies an opportunity to maintain a watching brief on an emerging area of science or technology and may allow them to collectively shape the direction of research carried out by academics, as well as gain early access to results (AURIL, 1997). Networking also offers opportunities for more formal collaborative linkages. According to the OECD (2002), informal networks between faculty and former graduates and between former public researchers and their lab of origin account for a large share of the total amount of knowledge exchanged between industry and public research centres.

There is evidence from several studies that the type of collaboration mechanism used tends to vary from one scientific or technological area to another (e.g. Faulkner & Senker, 1994; Rappert *et al.*, 1999; Meyer-Krahmer & Schmoch, 1998; Schartinger *et al.*, 2002). In science-based fields (e.g. biotechnology & chemistry), universities usually focus on basic research and industrial partners are mainly interested in the commercial and industrial implications of a scientific project and how they can be taken advantage of by their R&D departments; whereas in less science-based fields (e.g. mechanical & civil engineering), the solution of technical problems is a major concern of industry (Koch *et al.* 2000). The form that university-industry collaborations take also differs widely from country to country. In a study of university-industry R&D collaboration in the US, the UK and Japan, Rahm *et al.* (2000) show that collaborations in the US and the UK tend to share a number of similarities, while such activities in Japan are very different, mainly as a result of the nature of higher education, the cultural norms that dominate, as well as the dominant economic and legal structures.

Looking at the body of literature as a whole, it appears that despite the importance of informal linkages and collaborative research in terms of knowledge flows, many previous studies on industry-academia interactions have focused on formal mechanisms such as contract research and the commercialisation of university research results (technology transfer). Stewart (1999) notes that interactions such as the commercial use of university facilities or services where industry both sets its own goals and has a significant input to the activity (i.e. unequal input by participants), and where problem solving is immediate, can '*barely be called a collaboration*'. He also points out that the more recent 'networks' model of innovation (Stewart, 1999; p.40) places reduced emphasis on the direct commercialisation (linear model) of new knowledge created by academics and instead highlights the importance of multi-directional knowledge transfer between researchers.

To summarise this section, Table 2.2 shows the various types of interactions between universities and firms and classifies them by three dimensions defining their suitability in knowledge transfer: the degree of formalisation, the extent to which tacit knowledge may be transferred and whether personal interaction takes place. As stated earlier, the type of interaction is influenced by the motivations of industry and academia; these are described in the next section. In conclusion, this section has emphasised the importance of collaborative research for knowledge exchange but has also indicated the need for further research on the characteristics of such interactions, specifically what constitutes successful industry-academia collaborative research projects or networks? For example, what is the appropriate structure for such interactions in terms of formality, size (number of people), duration, type of research, etc., and what roles should the various participants involved play in the collaboration?

Table 2.2: Types of knowledge interactions between university and firms (from Schartinger *et al.*, 2001)

Types of knowledge interaction	*Formalisation of interaction*	*Transfer of tacit knowledge*	*Personal (face-to-face) contact*
Employment of graduates by firms	+/-	+	-
Conferences or other events with firm and university participation	-	+/-	+
New firm formation by university members	+	+	+/-
Joint publications	-	+	+
Informal meetings, talks, communications	-	+	+
Joint supervision of Ph.D. and Masters theses	+/-	+/-	+/-
Training of firm members	+/-	+/-	+
Mobility of researchers between universities and firms	+	+	+
Sabbatical periods for university members	+	+	+
Collaborative research, joint research programmes	+	+	+
Lectures at universities, held by firm members	+	+/-	+
Contract research and consulting	+	+/-	+
Use of university facilities by firms	+	-	+/-
Licensing of university patents by firms	+	-	+/-
Purchase of prototypes, developed at universities	+	-	+/-
Reading of publications, patents etc.	-	-	-

+: interaction typically involves formal agreements, transfer of tacit knowledge, personal contacts; +/-: varying degree of formal agreements, transfer of tacit knowledge, personal contacts; -: interaction typically involves no formal agreements, no transfer of tacit knowledge, no personal contacts.

2.3 *Motivations for & benefits to collaboration*

Understandably many academics see collaboration with industry as a way of gaining increased financial support for their research (perhaps reflecting the lack of public resources and the increasing costs of conducting research) and many industrialists are looking for new ideas from universities to drive commercial benefit. These are however not the only motivations that the two groups have to collaborate with each other, as the literature shows. Table 2.3

presents a list of motivations for industry-academia collaboration provided by Molina *et al.* (1997) and Table 2.4 shows a detailed list created by AURIL (1997) of the numerous potential advantages such partnerships can offer both parties. For the listing provided by Molina *et al.* the motivations listed first are usually the most significant motives behind interaction between university and industry. It is worth noting that the majority of the motivations or benefits listed in Tables 2.3 and 2.4 have also been identified in other studies based on surveys (e.g. Howells *et al.*, 1998; Meyer-Krahmer & Schmoch, 1998; Lee, 2000).

Table 2.3: Examples of Motivations for University-Industry Collaboration (from Molina *et al.*, 1997)

Industry	*University*
1. To obtain access to manpower (students and professors) 2. To obtain a window on science and technology, including access to knowledge, artefacts and technical information 3. To solve a problem, assistance with experimentation or get specific information unavailable elsewhere 4. To obtain prestige or enhance the company's image 5. To make use of an economical resource 6. To provide general support of technical excellence 7. To be good citizens or foster good community relations 8. To gain access to university facilities	1. Industry provides a new source of money. This helps diversify the university's funding base and provides opportunities for obtaining state-of-the-art equipment and facilities. 2. Industrial money involves less red tape than government money 3. Industrially sponsored research provides students exposure to real world research problems 4. Industrially sponsored research provides a chance to work on an intellectually challenging research programme which may be of immediate importance to society 5. Some government funds are available for applied research, based upon a joint effort between university and industry 6. To provide better training for the increasing number of graduates going to industry

In Tables 2.3 and 2.4, we can see that the two parties to a collaboration clearly complement each other in several respects, for example in terms of skills, finances, human resources, physical resources, and new ideas or techniques. Surveys based on participants involved in industry-academia collaborations have shown that for many academics the principal motivating factor is the desire for additional finances to support research (e.g. Howells *et al.*, 1998; Meyer-Krahmer & Schmoch, 1998).

Table 2.4: Advantages of research partnerships to Industry and Universities (from AURIL, 1997)

Advantages for Industry	*Advantages for Universities*
Outsourcing: getting research done by university researchers when the company is unwilling or unable to do it in-house	*Market awareness*: gaining insights into the research problems preoccupying particular companies or industrial sectors; developing new lines of (industrially relevant) research
Complementing the company's skills base: accessing skills and expertise within universities which company staff lack	*Maintaining momentum*: increasing the chance of sustaining existing research programmes and initiating new programmes by widening the customer base
Pursuing a multidisciplinary approach: deploying the multi-disciplinary teams which universities can more readily assemble	*Harnessing private and public funding*: bringing private (as well as public) funding to bear upon research programmes by developing proposals in partnership with one or more companies
Harnessing public funding: bringing public (as well as private) funding to bear upon company research problems by developing proposals in partnership with a university	*Complementing the university's skills base*: learning new techniques and skills, developed within companies
Complementing the company's physical resource base: accessing unique or specialist university-based equipment, facilities (and services) which the company lacks	*Complementing the university's physical resource base*: accessing state of the art or specialist company-based facilities or services which the university lacks
Recruitment made easy: finding the right staff for the job as a result of getting to know students, post-doctoral researches and academic supervisors	*Enriching teaching programmes*: obtaining the employer's perspective on the direction and content of teaching programmes; sourcing ideas for student projects and locating placement opportunities
Benefiting from new ideas: getting the inside track on emerging fields, enabling technologies and new ideas, generated within universities, which could benefit the company	*Sourcing job opportunities*: getting the inside track on possible job opportunities for graduates, post-graduates, post-doctoral researchers and academics
Opening up a window onto the world: keeping tabs on relevant developments elsewhere in the world via academics' extensive international networks	

For industrial researchers the exchange of knowledge is a significant motive as they need new knowledge in order to improve their products or processes, or to develop new ones. There is increasing awareness in industry, especially in small and medium sized companies, that new ideas from universities can make an important contribution to future profitability. The unrestrained nature of academic research makes it a fertile source of innovation for industry as it can generate ideas that are unlikely to arise during the course of the more channelled activities of the industrial laboratory (Konecny *et al.*, 1995). It is now widely recognised that increased interaction between diverse partners helps create new ideas by cross-fertilization of various problems and approaches to solve them (Hameri, 1996). Academic researchers also need new knowledge to support their personal research activities and therefore, their academic careers. Lee (2000) states that the most important motivational consideration for academics is to advance or complement their own research agenda (e.g. to secure funds for research and to test the application of their own theory or research).

The problem statement provided in Chapter 1 encourages us to also consider the benefits of university-industry research collaborations at the individual level - Katz and Martin (1997) demonstrate five main types of benefit to individuals from research collaboration: (i) 'sharing' of knowledge, skills and techniques; (ii) 'transfer' of (new, especially tacit) knowledge or skills; (iii) promotion of clash of views, cross-fertilisation of ideas which may in turn generate new insights or perspectives; (iv) provide intellectual companionship and wider network of contacts; and (v) enhance potential visibility of work. In his survey of participants in an R&D network in the Netherlands, Tijssen (1998) found that knowledge creation and transfer is a more important objective than technological development and innovation. Several surveys have found that many companies regard the exchange or employment of educated and highly skilled personnel (graduates) as the most important benefit and knowledge flow they gain from universities (e.g. Hicks *et al.*, 1996; Tijssen, 1998; OECD, 2002). This is not surprising as most universities are primarily education institutions so the production of highly educated graduates is the largest contribution they can make to knowledge transfer or dissemination. In this context, personnel mobility is very important as it enables the exchange of tacit know-how, skills, methods and techniques.

This section has reported on a wide range of motivations for and potential benefits from industry-academia collaboration. Because of the variety in opinion or findings on this aspect, there is a need to further investigate what the industrial and academic motivations (& benefits) are in the case of collaborative research projects and networks in the UK, and subsequently to find out whether the different motivations of the various parties have an important influence on collaboration effectiveness.

2.4 Barriers to & problems of collaboration

Industry and universities might be well motivated to collaborate but there are many barriers to such involvement and the considerable potential benefits are often not realised in practice (Barnes *et al.*, 2002). These barriers relate both to the initiation of collaboration and the process of collaboration. A wide variety of problems that occur at the university-industry interface have been revealed in previous studies. However it is not possible to accommodate all of them in this section and the commentary is thereby restricted to a consideration of the most common barriers. Published literature suggests that the most significant problems were in general related to: institutional differences (different cultures and structures), restrictions in information dissemination due to confidentiality issues, intellectual property rights, and ineffective communication. Each of these barriers to effective collaboration are discussed below. According to Rahm *et al.* (2000), the most significant of these barriers is probably the fundamental differences in the missions, objectives, cultures, and research interests of companies and universities.

In their study of industry-academic linkages in the UK, Howells *et al.* (1998) found that most universities saw differences in the research objectives between industry and academia as the most important barrier to establishing working relations with industry. Differences in objectives has also been shown to be a significant barrier in several other surveys (e.g. Tijssen & Korevaar 1997; Burnham 1997). Companies and universities naturally have different research objectives and tactics. Research in industry usually tends to be strategic or applied in nature and has a relatively short horizon. It is generally carried out with a specific application in mind, which will lead to ultimate commercial benefit (AURIL, 1997). By comparison, university research traditionally tends to be more basic, fundamental or speculative in nature. It is usually carried out for the benefit of generating and disseminating new knowledge, to train postgraduate researchers for careers and to continually update the university's teaching programmes. Research objectives also tend to vary between different industrial sectors and universities, even within the same sector or university. Universities and companies may follow quite different strategies to achieve their research aims even if the objectives are quite similar. Even individual departments or research groups within a university may use different tactics. The key differences between the research operating characteristics of industry and universities are summarised in Table 2.5.

Table 2.5: Operating Characteristics: Academia vs. Industry (developed by author)

Academia	*Industry*
▪ Relatively long time horizons	▪ Relatively short time horizons
▪ Knowledge growth imperative	▪ Milestone driven
▪ Basic research	▪ Applied research
▪ Bias towards 'openness'	▪ Proprietary bias

Konecny *et al.* (1995) express the view that it is important to recognise that although there may be some similarities in academic research and industrial R&D, they are essentially different activities and these differences can therefore, present constraints to the interactions of academics and industrial researchers. Table 2.6 shows an outline of the principal differences between academic research and industrial R&D in terms of purpose, choice of topics, predominant expertise, approach, publication of results and value systems. As a result of the differences in their operating characteristics, industrial researchers may have the perception that their university counterparts are not good at (for example) addressing practical needs, handling confidential information, timely delivery of results, and being flexible in their approach. On the other hand, university researchers may be concerned about the loss of academic freedom and freedom to publish, industry's concern for timely results, and their emphasis on the short-term (Konecny *et al.*, 1995). These differences can cause misunderstandings, lack of trust, frustration, and delays in collaborative projects.

Table 2.6: Academic Research and Industrial R&D compared (from Konecny *et al.*, 1995).

Academia	***Industry***
Purpose	*Purpose*
▪ To advance knowledge of the physical world.	▪ To advance company business against competition.
Choice of Topics	*Choice of Topics*
▪ Chaining based on experience.	▪ Match between company needs and individual experience.
Predominant Expertise	*Predominant Expertise*
▪ Phenomena and techniques.	▪ Products and processes of interest to the company.
Approach	*Approach*
▪ Completeness is important.	▪ Timeliness often more important than completeness.
Publication of Results	*Publication of Results*
▪ Usual.	▪ If they are not of value to competitors.
Highly Valued	*Highly Valued*
▪ Advance of subject. ▪ Intrinsic virtues of work.	▪ Impact on the business.

There are some indications in the literature that small companies in particular have difficulty forming relationships with university researchers because they tend to look for immediate solutions to problems and have a shorter term focus than larger companies, thus presenting difficulties for academics who like to work over longer timescales. Another issue commonly associated with small companies is corporate instability (e.g. take-over, financial difficulties, restructuring) that is said to be 'disruptive' to collaborative projects (Barnes *et al.*, 2002). According to the BHEF (2001), the frequent turnover of company project managers is the most disruptive personnel change that affects collaborations. According to Stewart (1999), science-based firms that possess R&D departments have fewer problems with academics because they share similar values, whereas craft-based traditional firms have great difficulties in communicating with university researchers because their cultures are so far apart.

With regard to information dissemination, academics and companies have very different perspectives and methods - university research results are generally freely disseminated in publications as this is the dominant *modus operandi* of academic science, whereas industrial research is mainly treated as private property to avoid revealing something of value to competitors and usually ends up in patents or other types of protected intellectual property (IP). Industrial collaborators therefore often ask their academic counterparts to sign agreements to delay or otherwise restrict the free flow of information (Stewart, 1999). There is concern that such publication delays and non-disclosure requirements may harm the open academic research environment. Carayol (2003) provides some evidence that industry-academia collaborations can alter the publishing and disclosure behaviours of both academics and students who are involved in such projects. Students are often involved in collaborative research projects and the need to protect their academic interests makes the negotiation of confidentiality and IP terms very difficult. The challenges and consequences of maintaining confidentiality are said to be particularly acute in the case of students (BHEF, 2001). There have also been cases reported where student time has been misused by a collaborating company, for example by being treated as an employee (GUIRR, 1999). In their study of six collaborative research projects (more information on p. 30), Barnes *et al.* (2002) found the role of doctoral students within such projects to be the most significant cultural issue because such students have clearly defined requirements with regard to doctorate-level research. The factors that affected the students in their study include frequently changing project objectives and pressure to produce results quickly because of industry's short term focus.

Companies and universities also often have different views concerning IP ownership. For example, the chemical industry tends to prefer owning any IP generated in a research partnership since the costs of development, investment in plant, etc., are so vast that they cannot be justified without an advantageous commercial position (AURIL, 1997). Stewart (1999) states that intellectual property rights (IPR) is one of the main causes of conflict found in partnership disputes between universities and industry, mainly because the exact origins and nature of the knowledge underlying it are very difficult to define. There are often problems in negotiations on the ownership, value and use of IP and there is evidence that the current funding mechanisms are making the situation worse (see Stewart, 1999 for a more comprehensive overview of the problems of this issue). The overall contribution made by each partner relative to the others usually determines ownership of research outcomes and any associated IP (AURIL, 1997).

These problems and barriers may be overcome with careful preparation and planning as the next section on management and best practice will show. To summarise this and the previous section, Table 2.7 presents a summary of the most important motivations and barriers to industry-university research partnerships.

Table 2.7: Summary table of key motivations and barriers in university-industry research collaborations (developed by author)

Motivations	*Barriers*
▪ Exchange of knowledge, skills & techniques, including tacit knowledge & new ideas ▪ For universities - access to additional financial resources for funding research ▪ Exchange of educated or skilled human resources ▪ Access to state-of-the-art facilities (equipment, laboratories, etc.) & training or support services	▪ Differences or conflicts in missions, research objectives, culture (organisational) & operating characteristics (e.g. time frames, research type i.e. basic v. applied, value systems, etc.) ▪ Information dissemination restrictions due to differences in views or modes of publication ▪ Conflicts over intellectual property rights

In conclusion, this section has highlighted several important barriers that relate to industry-academia collaboration and has identified the need for research which informs how such problems can or may be overcome. For example, how can the competing objectives of the various participants be balanced? how can industry's requirement for secrecy and academic's requirement for freedom be balanced?, and what are the appropriate solutions for conflicts in IPR? The role and experiences of students who are involved in collaborative research is clearly a developing area of concern in the literature; one which further understanding of would benefit collaborative processes.

2.5 Management of collaboration & best practice issues

> *'Structuring and managing partnerships that produce real gains for all partners takes experience, careful planning, and ongoing attention.'*
> (GUIRR, 1999)

Establishing and maintaining successful university-industry research partnerships is a considerable challenge as industry and universities have different motivations to cooperate, or not to cooperate, with each other (Rahm *et al.*, 2000). Setting up effective collaborations is very difficult because it involves satisfying the interests and requirements of individuals belonging to different organisational cultures and business practices (Molina *et al.*, 1997). As the development of many industry-university relations depends to an enormous extent on individual and institutional initiatives, which are mostly of an informal nature, it is difficult to predict and plan this process (OECD, 1984). The effective management of such linkages has therefore always been a challenge for both sides (Burnham, 1997). Collaborations between disparate partners need considerable management effort to be successful (Dodgson, 2000).

There has been increasing interest worldwide in the consideration and identification of mechanisms for effective university-industry collaboration. Recently, many authors have provided prescriptive advice and guidelines for promoting good university-industry relationships (e.g. BHEF, 2001, Starbuck, 2001; Barnes *et al.* 2002). Several sets of guidelines have been developed based on forums of experienced individuals discussing critical issues in such collaborations based on their experience, particularly in the US (e.g. NAS, 1997; GUIRR, 1999; BHEF, 2001). In the UK one 'guide to best practice' for industry-university research partnerships was recently published jointly by the university-based Association for University Research and Industry Links (AURIL) and the Inter-Company Academic Relations Group (ICARG) of the Confederation of

British Industry (AURIL, 1997). They pointed out that there is no unique solution to the question of how to structure the management of a collaborative project as it depends on the nature and demands of the project, as well as the circumstances of the partners.

A number of common key factors or best practice elements for the effective organisation and management of university-industry research partnerships have been identified in the literature including:

- Mutual trust and good personal relationships (that develop over time) (Schartinger *et al.* 2002; Rappert *et al.*, 1999; Senker *et al.*, 1998);
- Good project management (e.g. progress monitoring, effective communication) (Starbuck, 2001; AURIL, 1997);
- Mutual understanding of motivations, interests and needs (organisation missions) (Brannock & Denny, 1998; Konecny *et al.*, 1995);
- Clearly specified objectives and expectations (at outset) (e.g. Barnes *et al.*, 2002; Burnham; 1997);
- Frequent, clear and open communication (& feedback) (BHEF, 2001; AURIL, 1997; NAS, 1997)
- Commitment (& continuity) of both partners - helped by mutual goals and benefits (Barnes et al., 2001);
- Close alignment of expertise and interests of parties (Molina *et al.* 1997);
- Agreements on publication issues, roles and responsibilities (BHEF, 2001; Starbuck, 2001).

According to Konecny *et al.* (1995), the differences between academic and industrial research cultures are inadequately considered by many in academia and government agencies, and to a lesser but still significant extent in industry. They also suggest that collaborations between universities and industries should include a balanced mixture of research devoted to basic and to applied aspects, so as to improve mutual understanding of each party's capabilities, needs, obligations, attitudes and roles. The BHEF (2001) in recommending the type of research that could be mutually beneficial, emphasise that it should be ethical, publishable, basic or slightly applied.

Previous research suggests that careful account should also be taken of confidentiality and publication needs, and of IP ownership. Collaboration agreements may help speed up the research contract negotiation process but according to the BHEF (2001) they are difficult to develop and implement because business practices in different industrial sectors require disparate agreements. In their paper, Brannock and Denny (1998) provide a detailed account (including examples) of the four main and most important issues that form the core of all types of agreements between a university and its industrial partner: publication rights, IP rights, confidentiality provisions and indemnification issues. Rahm *et al.* (2000) recommend putting procedures in place to deal with any conflicts of commitment and interest that may arise in the collaboration process. Also personnel changes which are a part of corporate life should be expected and planned for accordingly (BHEF, 2001). If the collaborative project involves students, it is recommended that they should also be informed at the outset of the negotiated overall scope and goals of the project, and of any confidentiality and intellectual property expectations (Starbuck, 2001).

Another important aspect that has been discussed in the literature is 'flexibility' in university-industry relations, usually the result of the efforts of single individuals operating with a minimum of organisational restrictions (OECD, 1984). It is recommended that management processes are flexible enough to react to changes in the external environment, for example, industrial partner changes and changes in project direction or strategy (Barnes *et al.*, 2002). Reaching agreement therefore takes patience, flexibility and an understanding of the different, but often complementary, objectives of both parties (Brannock & Denny, 1998). The BHEF (2001) believe that involving experienced people in negotiations can smooth the process, particularly when individuals with a 'dual' background, i.e. with both academic and industrial experience, play a role.

Several authors have also mentioned that prior collaboration experience helps (e.g. Molina *et al.*, 1997; Barnes *et al.*, 2002).

The significance of ensuring that there are adequate levels of contact and open communication channels between collaborators in industry-university research partnerships was highlighted by many authors in the literature as the following quotes show:

> *'If one had to identify any single factor that was most essential for the successful management of a collaborative project, it would probably be communication between the partners.'*
>
> (AURIL, 1997)

> *'Communication is perhaps the most critical management issue in collaboration.'*
>
> (BHEF, 2001)

The importance of personal (i.e. face-to-face) contacts for the security of relationships between academics and industrialists has been emphasised many times. Face-to-face interactions can result in strong interpersonal networking contacts between the two parties. There is evidence that industrial R&D managers consider workshops, where they meet and discuss well-defined issues in depth with university researchers, to be a powerful method of learning from university research especially for new products or new areas of research (Konecny *et al.*, 1995). In successful personal contacts, understanding develops and relations of trust become established over time.

Many authors in the literature claim that trust is central to the effective operation of collaborative relationships. Jones and George (1998) state that trust is a necessary condition for cooperative behaviour among individuals, groups and organisations. According to the BHEF (2001), mutual trust is perhaps the most important of the many ingredients in successful negotiations. Trust is important for the development and sustainability of collaborative relationships because it helps overcome the social problems of collaboration (Newell & Swan, 2000). Schartinger *et al.* (2002) state that trust is a critical condition in collaboration characterised by high uncertainty of results, the involvement of highly sensitive knowledge, and low suitability of research results for one partner. In their study of knowledge exchange in networks, Rappert *et al.* (1999) argue that trust is a key element in ensuring the exchange of essential knowledge, both codified and tacit. When a high level of trust exists, there is greater confidence and less uncertainty in relationships; therefore both partners are more willing to share ideas, needs, and feelings (Santoro & Gopalakrishnan, 2000). Senker *et al.* (1998) state that trust building, mutual respect and understanding are vital prerequisites to success in formal relations and that these are more easily built up informally. As well as direct personal interactions (i.e. face-to-face communication), trust helps to build up a joint 'language' and a joint research culture (Schartinger *et al.*, 2002).

A variety of factors contribute to the development and maintenance of trust in collaborative research. This is demonstrated in Newell and Swan's (2000) study which explored the evolution of trust within an inter-university, multi-disciplinary research network. They studied the development of three different types of trust, based on typologies described in the literature, as follows:

1) 'Companion' trust – based on judgement of goodwill/personal friendships;
2) 'Competence' trust – based on perceptions of the other participants' competence to carry out the tasks that need to be performed;
3) 'Commitment' trust – stems from the contractual agreements between the parties and developed on an institutional basis.

Their research showed that it is useful to analyse different types of trust for knowledge exchange in multi-disciplinary collaborative research networks because different types of trust interrelate in specific ways, depending upon the particular motives holding participants together. In the literature trust is often believed to be simply built through a process of continued interaction or communication. Good interpersonal relationships and effective communication are also often seen to be critical in maintaining trust between collaborative participants. Newell and Swan's research however highlighted problems of developing trust (in particular 'competence' trust) in situations where participants come from very different epistemological and ontological positions, a very common situation in a multi-disciplinary research networks. Their results suggest that simply communicating and interacting does not guarantee the development of trust, particularly in multi-disciplinary and multi-institutional collaborative research networks. This raises the question of how to establish trust-based interaction within such networks. Newell and Swan believe that focusing on formal mechanisms (e.g. planning mechanisms) in the absence of informal mechanisms which look at interpersonal integration (e.g. communication & social co-ordination mechanisms) is unlikely to successfully help trust development. In their paper, Newell and Swan also raised questions about the effectiveness of interdisciplinary research and the usefulness of the current emphasis on multi-disciplinarity, suggesting that it may actually reduce rather than increase the creation and diffusion of innovative ideas by research networks.

The OECD (1984) points out that the importance of individual initiative in the formation and development of networks with industrial and academic participants should not be underestimated. Despite the existence of formal agreements, the ultimate success of collaborative projects largely depends on the people involved (Biemans, 1990). The success of the collaboration depends primarily on the interest and enthusiasm that participants bring to the joint research effort and also relies heavily on the strength of the personal relationships (BHEF, 2001). Stewart (1999) states that the success of a partnership is based on the ability of the participants to customise their relationship and to develop a format for their interaction that suits them. Therefore the type of relationship formed is as individual as the partners involved and is determined by their particular needs, particular experiences and expertise.

To end this section, findings from a recent in-depth study of management practice within university-industry collaborative research projects in the UK which led to the development of a good practice model are presented. This study is of relevance to the research presented in this thesis because it looks at participants' perspectives on factors influencing the effectiveness of collaborative projects in the UK. Barnes *et al.* (2002) evaluated six collaborative projects based at the Warwick Manufacturing Group (University of Warwick) in order to identify factors which, if managed correctly, increase the probability of a collaboration being perceived as successful by both academic and industrial partners (the measures used for this study are described in Section 2.6). Figure 2.2 shows the good practice model which includes all the factors found to have had a significant impact on the perceived success of the case study projects (organised into six key areas).

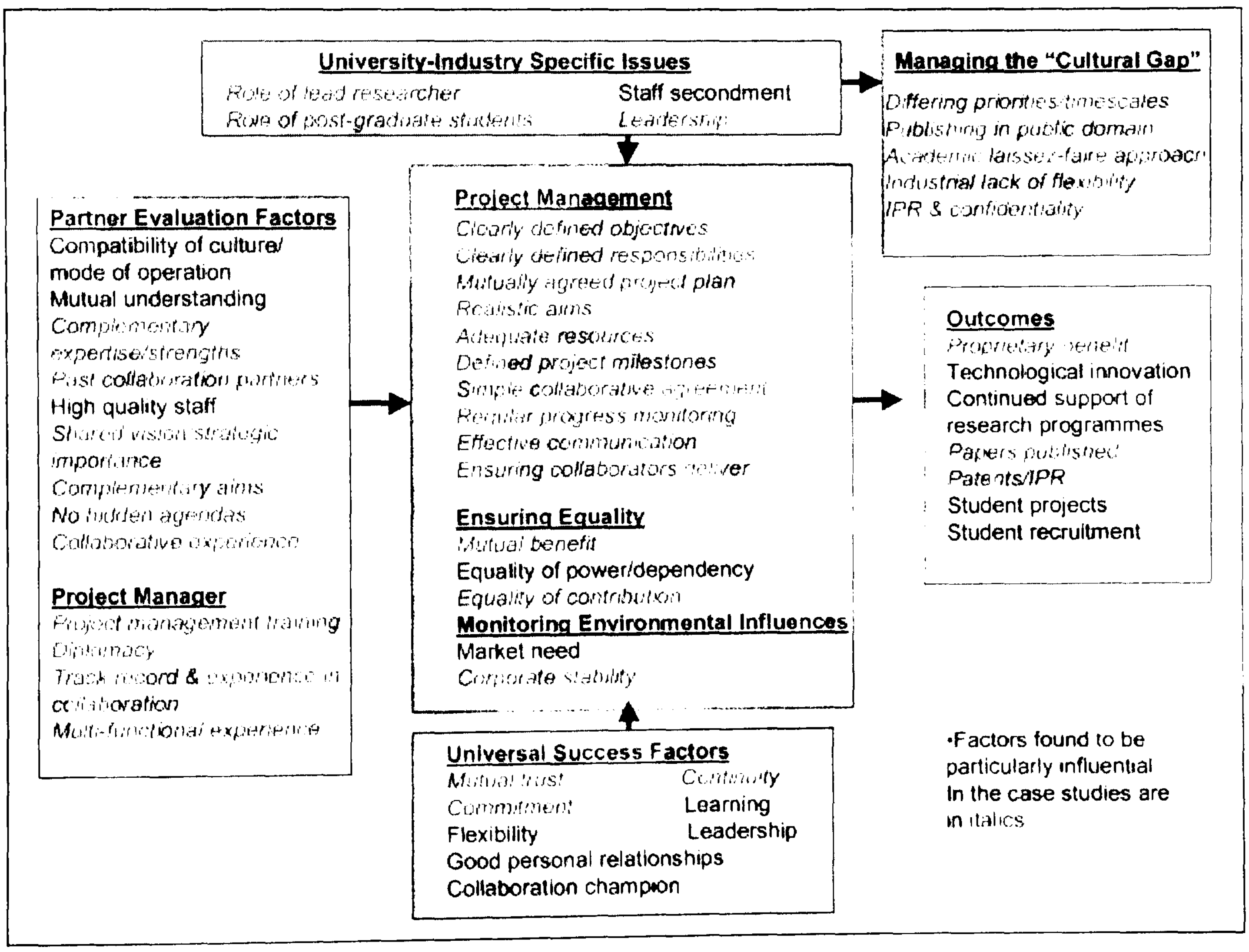

Figure 2.2: Good practice model for the effective management of collaboration (from Barnes *et al.* 2002)

Although the model is based on the findings of only six case study research projects based at one academic department, Barnes *et al.* (2002) claim that many of the success factors included in the model are also supported by research conducted by other workers in the field (published in the literature) indicating a broader applicability for the model. They did however also mention that further validation of their findings is needed though additional cases involving other universities and industries engaged in similar collaborative projects – this would enable further testing and refinement of their model and thus maximise its usefulness as a tool for practitioners. In the discussion chapter of this thesis (Chapter 6) we will be looking at how the findings of the research activities described in Chapters 4 and 5 inform Barnes *et al.*'s model. Barnes *et al.* conclude that, because some common themes emerged from their study:

> *'a standardised good practice model for the effective management of collaborations would provide a useful management tool which could be applied to future collaborative research projects, as a means of systematically improving collaboration management practice and thereby improving the probability of collaboration success.'*
>
> (Barnes *et al.*, 2001; p.283)

In conclusion, this section has explored a wide range of issues that are considered important when managing industry-academia research collaborations. It has also identified a number of factors which require further investigation including: how effective are the current management strategies for specific collaborative ventures (networks & projects) in the UK? Would a standard management (or good practice) model be appropriate? How prescriptive or flexible should the management structure be? Does a collaboration agreement help? The importance of appropriate modes of communication between the various participants in industry-academia relationships was also emphasised in the reviewed literature, raising an additional set of research issues around appropriate methods of communication (meeting structure, size, frequency & procedure) and modes of communication (e.g. face-to-face, internet, etc.).

2.6 UK government incentive schemes

In recent years a wide variety of schemes and frameworks have been developed to encourage and facilitate research partnerships between industry and universities. In particular, numerous formal schemes have been set up that are part-funded by third parties, especially the UK Government and the European Commission. Such schemes and frameworks facilitate a range of types of research partnership varying in duration, strength, the level of financial and other resources required to underpin them, and the extent to which public funding may be available to help support them (AURIL, 1997). Some frameworks have been set up by universities themselves either unilaterally, or by working in conjunction with industry. For example, many universities have established industrial liaison offices to facilitate contacts with industry, in particular with small and medium sized companies. Recently the results of an EU benchmarking project assessing the impact of different framework conditions (e.g. public promotion schemes, intermediary infrastructures, legislation & regulation and institutional settings) on industry-science relations in different countries have been published (Polt *et al.*, 2001; OECD, 2002). This work has shown that such framework conditions may influence the level, effectiveness and efficiency of knowledge exchange between science and industry. They can either stimulate the relationships by reducing barriers and setting incentives, or impede relations by creating barriers or setting disincentives.

In the UK, the policy context is of fundamental importance for industry-science linkages (OECD, 2002). Significant emphasis on the support of industry-academia collaborations started in the early 1990s as a result of the 1993 government White Paper on the UK's science and technology policy *'Realising our potential'* (HMSO, 1993) which set out policies designed to encourage closer contact and exchanges between the science and engineering base and industry. From the point of view of the government, the primary objective of such linkages is generally to contribute to innovation and consequently to national economic growth. Since then, various institutions including government, their agencies, industrial sectors, universities and intermediaries have contributed to the development of a large number of initiatives with the aim of enhancing collaboration between industrialists and academics. In general terms, the different UK innovation policies reflect the theoretical understanding of the innovation process at a particular time. Thus some of the older policies that encourage universities to commercialise their research reflect a 'linear model' (uni-directional transfer of knowledge from science to technology) whereas the more recent ones take into account the newer 'networks model' (knowledge flows in many directions through a maze of networks) (Stewart, 1999). Table 2.8 shows some of the major schemes developed by the UK government to promote and support collaboration between industry and universities. The LINK scheme is the government's oldest and principal mechanism for encouraging pre-competitive collaborative research between the science and engineering base and industry (for more information on this scheme, see Stewart, 1999). It helps build lasting linkages between industrialists and academics but there have been some criticisms that the programme is too formal and inflexible in its structure and that it is not a suitable funding mechanism for encouraging links with SMEs (small and medium enterprises) (Stewart, 1999).

Based on an assumption that there is a significant cultural divide between universities and (in particular craft-based) commercial companies, the UK government developed policies aimed at helping the two sides communicate more effectively by using people as 'agents of change' (Stewart, 1999). This is done by placing highly trained people from universities within companies. Examples of such 'people based partnership' schemes include the Teaching Company Scheme (now called Knowledge Transfer Partnerships), the Co-operative Awards in Science and Engineering (CASE; see Table 2.8) and the Faraday Partnerships. These schemes help knowledge flows between all the parties involved and therefore reflect the networks model of innovation. Also as Stewart (1999) points out, their greatest value lies in their ability to bring about cultural change within UK industry, mainly by changing companies' attitudes towards hiring graduates. As indicated earlier, the supply of skilled graduates is one of the most important benefit that industry gains from collaborations with universities.

Table 2.8: Major Public Promotion Activities for Industry-Science Relationships in the UK (from OECD, 2002)

Activity	Year introduced	Objectives	Type(s) of industry-science interaction
Foresight	1993	• To develop visions of the future – looking at possible future needs, opportunities and threats, and deciding what should be done now to make sure we are ready for these challenges • Build bridges between senior people in business, science and government, bringing together the knowledge and expertise of any people across all areas and activities	Networking (but limited involvement of commercial management)
LINK	1985	• To encourage research collaboration between industry and the science base	Collaborative research
Faraday Partnerships	1999	• Intermediary organisations hosting research and technology adoption and translation activities (which can involve universities)	Technology adaptation, facilitating collaborative research, personnel mobility, training & education
University Challenge Fund	1999	• Provides support to universities or consortia of universities to set up local seed funds supporting early-stage commercialisation	Knowledge transfer through spin-outs, IPR, develop prototypes
Science Enterprise Challenge (SEC)	1999	• To encourage transfer of S&T innovation to the business sector by establishing "centres of enterprise" in universities to: ▪ teach enterprise and entrepreneurship to science and technology students ▪ make ideas and know-how available to business to support competitiveness and wealth creation ▪ encourage the growth of new businesses by supporting start-ups, including spin-out companies based on innovative ideas developed by students and faculty within the universities	Training & education, technology transfer
Higher Education Innovation Fund (HEIF)	1998	• Funding for the establishment of centres of expertise in HEIs, ISR-oriented training for HEI staff, "one-stop shops" for business partners	Technology transfer, contract research, networking, personnel mobility
Joint Research Equipment Initiative (JREI)	1996	• Funding of equipment in areas of high-quality research	Contract research, collaborative research
Collaborative Awards in Science & Engineering (CASE)	n.a.	• Provides grants to students carrying out doctoral research addressing industrial problems and jointly supervised by HEIs and firms • There is also an Industrial CASE studentship scheme where industrial partners choose an academic partner for research training, and a CASE for New Academics scheme that provides a route for new academics to build links with a company at an early stage in their career through co-supervision of a CASE student	Training & education

Whilst the schemes listed in Table 2.8 support the broad objectives of UK innovation policy, there is concern that an emphasis on commercialisation by spin-offs and licensing of technology has distracted attention from the challenge of fostering relations with existing firms, particularly small companies (OECD, 2002).

In recent years, collaborative research networks have become very popular with some funding agencies. The Engineering and Physical Sciences Research Council (EPSRC), for example, has supported the establishment of over a hundred technology area networks that bring together diverse groups from universities and industry with the aim of encouraging the transfer of ideas, techniques, and scientific and technological expertise between disciplines, between universities, and between academia and industry (EPSRC, 1999). The networks are funded over a three-year period after which they are expected to be financially self-sustaining. Applicants for network funding are encouraged to be innovative in the choice of mechanisms for the operation of a proposed network and there is particular interest in interdisciplinary and multidisciplinary networks. The networks are expected to have clearly defined objectives, target and performance indicators that allow them be evaluated, and clear plans for the dissemination of information and results, not just amongst network members, but also to the wider community. They also recommend the establishment of a website as well as a diversity of communication activities, for example, workshops to provide face-to-face meetings which are considered to be more effective than electronic communication alone. In a report on one EPSRC funded Network on the Control and Prevention of Odour Emissions based at Cranfield University, it was emphasised that there is no single model for the formation of a successful network and that one of the most important aspects of network activity is communication (Maclean, 2001).

It is also worth mentioning here that there have been criticisms, particularly from industry, that the incentive schemes for academics do not sufficiently reward or motivate them for collaborating with industry (OECD, 2002). The Research Assessment Exercise (RAE) has frequently been identified as a barrier because of its focus on academic excellence in disciplinary traditions and on publications to evaluate the quality of research work being done in universities.

In conclusion, the effectiveness of current UK government schemes for supporting industry-academia collaborative research needs to be explored further, in particular the 'people based partnership' schemes (e.g. LINK, CASE). For example, do they provide adequate levels of support in terms of organisation, funding, and guidance, and do they help change individuals' attitudes and awareness of collaborative research?, etc.

2.7 Evaluation of industry-academia collaboration

In the past, universities saw little need to monitor the extent to which academics devoted their research time to industrially relevant work, largely since the direction of such research was seen as vital to academic freedom (Rahm *et al.*, 2000). Over the past decade there has been a rapid change in this attitude, as both universities and governments seek to influence the level and effectiveness of university-industry relationships. Increasingly detailed statistics have been developed in recent years and large-scale surveys have been carried out providing useful evidence of the continuing increase in and changing nature of university-industry interactions (e.g. Howells *et al.*, 1998; OECD, 2002). These statistics however do not represent the entire picture as they do not map (for example) informal relationships, knowledge flows ('tacit' benefits) and the nature (intellectual aspect) of the relationships between industrialists and academics. The OECD (2002) states that governments generally lack information and tools to monitor industry-science relations and evaluate their efficiency.

Recently there have been an increasing number of qualitative and quantitative studies evaluating the effectiveness of industry-academia collaborations including innovation, technology transfer or commercialisation, knowledge transfer or flows, specific scientific or technological progress, and the promotion of collaboration within certain countries or regions. Most studies are detailed empirical observations focusing on links in narrowly defined fields of research or technology (case studies), on the contribution of university research to knowledge production and on certain interaction types (particularly commercialisation activities) (Schartinger *et al.*, 2002). Because of the wide range of collaboration types and outputs from these activities, no single measure is fully able to capture the whole range of industry-academia collaborations. The authors who carried out the EU benchmarking project mentioned above (Polt *et al.*, 2001) demonstrated the difficulties of evaluating and measuring the effectiveness and efficiency of the various linkages between industry and science for knowledge exchange and therefore innovation. They developed a general model for assessing industry-science relations (ISR) based on the view that they are the result of market decisions by actors on the "knowledge market" (Figure 2.3). The model was used to analyse the impact of different framework conditions on ISR in different national innovation systems.

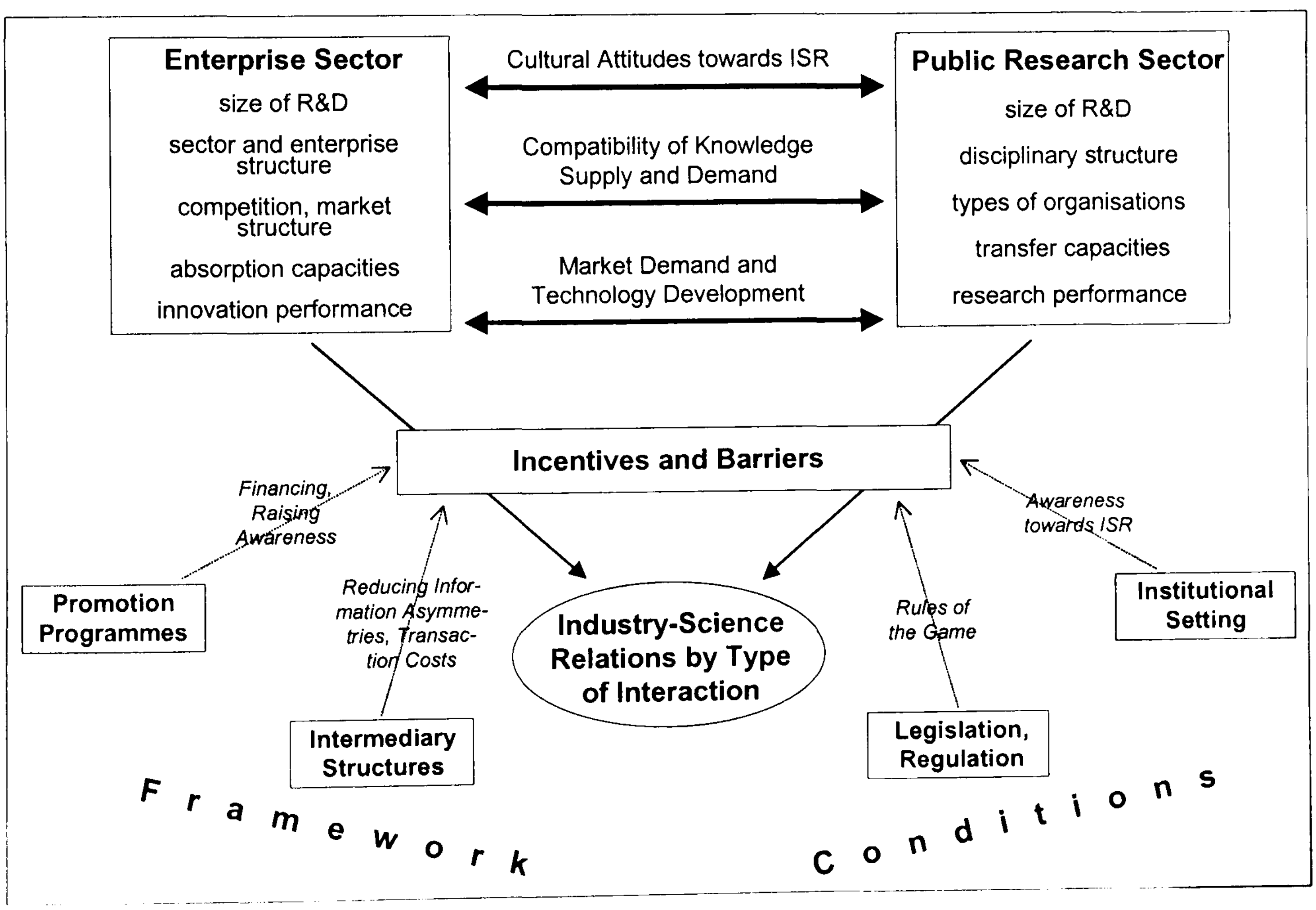

Figure 2.3: A Conceptual Model for Analysing Industry-Science Relations (from Polt *et al.* 2001).

The model shows the numerous variables that affect ISR including the characteristics of the main actors (enterprises & public research institutions) and the different framework conditions.

In their paper, Rahm *et al.* (2000) also commented on the difficulties inherent in measuring the effects of university-industry collaboration. They state that the main obstacle to defining the wider effects of collaboration is in measuring the flow of ideas, which are not subject to legal protection or payment. The reasons that many companies collaborate with universities are a lot broader than just the development of well defined new products; these include access to a wider range of ideas, expertise and "know how" – a process often designated as "knowledge transfer" (Rahm *et al.*, 2000). As knowledge transfer from universities to industry is a lot more complex than the undertaking of individual projects with specific results in mind, measurement of the outcome of such relationships is consequently problematic. Awareness is needed of the characteristics of knowledge involved within university-industry relationships (both at the organisational as well as the individual level). One study however, has directly addressed the issue of knowledge transfer. Faulkner and Senker (1995) considered knowledge flows across the university-industry interface in terms of science and technology inputs (STIs), which included a variety of forms of codified and tacit knowledge including knowledge of particular fields, technical information, and skills. STIs were examined in terms of sources, impacts, and the channels adopted in academic-industry relations.

Because of the difficulties in measuring industry-academia collaborations, most authors use simpler measurement techniques including bibliometrics and questionnaires or interview surveys. The use and limitations of bibliometric techniques to measure or characterise industry-academia research collaboration is discussed in the bibliometric study in Appendix 2A (Section 2). Several authors have used both bibliometrics and surveys to characterise the effectiveness of large research networks (e.g. Wen & Kobayashi, 2001; Tijssen & Korevaar, 1997; Tijssen, 1998). Most of the authors cited in this review used surveys to obtain the perceptions of participants involved in industry-academia partnerships or networks. In his study, Lee (2000) employed a 'simplified' measurement system called 'behavioural outcomes' – that is the perceived benefits of collaboration participants based on their experience of current or recent collaborative projects (e.g. degree of satisfaction). Barnes *et al.* (2002) also evaluated the success of the collaborative projects in their study on the basis of participants' perceptions - the value of the research outcomes to individual partners and how well their expectations had been met. They also used objective measures of innovation to balance these subjective measures, based on measurable outcomes such as the number of published journal papers, the number of patents filed and evidence of new product, process or technology developments. They justified their emphasis on the perceptions of the participants by noting that *'collaborative ventures are often perceived as failures despite some significant technological and/or tangible outcomes'* (Barnes *et al.*, 2002; p.273) and such perceptions may influence the decision to collaborate in future.

The way the effectiveness of an industry-academia relationship is measured therefore depends on how 'success' or 'efficiency' is defined either by the author or by the participants involved in collaboration (industrialists, academics & government), and on the type of relationship being observed. In a workshop on industry-academia research collaborations run by the National Academy of Science (US) (NAS, 1997), the participants agreed that:

> *'...the most successful partnerships include a system of mutually defined metrics to measure success and satisfaction, and to foster continuous improvement in the processing, functioning, and effectiveness of the partnership.'*

This section has highlighted the difficulties and uncertainties in both defining and measuring the effectiveness of industry-academia collaborative relationships. The review indicates that further research on how the various individuals (i.e. collaborative research funders, facilitators, and participants) involved in collaborative research projects or networks in the UK define 'successful' or 'effective' collaboration, as well as how the relationships are monitored or evaluated is desirable, i.e. what measures or metrics (both objective and subjective) are currently used?

2.8 Summary

The literature survey presented in this chapter has provided us with an extensive range of information and knowledge on the various aspects of university-industry relationships and has demonstrated the complexity of this topic. It has revealed a wide range of channels by which knowledge is transferred between university and industry actors and which provide a number of potential benefits in both directions. It has also helped us identify the various barriers and constraints that may occur in such relationships as a result of differences in the purposes, cultures, procedures, value systems and incentives of universities and companies, making communication and collaboration challenging. We have seen how the ability of universities and industry to overcome the barriers and establish successful collaborations has been found to depend on the forms of linkage mechanisms and communication channels established. It also depends significantly on the individuals involved in the relationship and how they organise and manage the collaboration.

The effectiveness of university-industry relationships has clearly become a subject of great concern in recent years to academics, industry leaders and policymakers and increasing attention has therefore been given to the consideration and identification of mechanisms for effective collaboration. Various suggestions and guidelines have been put forward by several authors in this respect. It is widely acknowledged that the most important element of successful collaboration is free flowing two-way 'communication'. There is some evidence that university-industry research relationships are becoming more efficient, particularly in recent years, as a result of changing structures, cultures, perceptions (increased appreciation, awareness, mutual trust) and greater flexibility of both parties.

Conversely there are concerns about the possible deleterious effects of industry-academia partnerships and also the impact of government emphasis on innovation and the commercialisation of research on the traditional missions or activities of universities. Despite the demonstrable social and economic benefits, such an emphasis could be modifying the public research agenda from basic to more applied (commercial) research. Intellectual property and confidentiality agreements may also be restricting knowledge and information flows in the naturally open academic environment. Academic excellence has been stated to be an important, but not necessary, prerequisite for successful interaction of universities with industry, in particular large science-based firms (OECD, 1984). There clearly needs to be a balance between helping industry (confidentiality) and allowing academics freedom and flexibility. It is believed that knowledge management may be a key mechanism in managing industry-academia relationships without endangering the basic objectives and missions of each partner (Saussois *et al.*, 2001).

Most recently, there has been increasing awareness of the role played by students in collaborative research. Despite the challenges of protecting their academic interests, the benefits of projects which involve students include the exchange of tacit knowledge and skills, and allowing companies the chance to evaluate students as potential employees. The role of students is an aspect that has not received much specific attention in the literature. It is deemed important because the academic objectives of universities necessarily favour the inclusion of students (doctorate & postgraduate) in collaborative projects and there is a lack of guidelines for their deployment in such projects (Barnes *et al.*, 2002).

It is also widely acknowledged that informal linkages and collaborative research are very important for knowledge exchange. There are, however, only a few studies that investigate the cognitive aspects of such types of interaction in detail, particularly in the UK. There also appears to be a lack of best practice guidelines based on such in-depth studies. Further research is needed on the effects of individual personal skills, competencies and attitudes in university-industry research collaborations. As stated by Scott *et al.* (2001), knowledge and research skills can be seen as capabilities embodied in researchers and the institutional networks within which they work, and scientific knowledge requires a substantial capability on the part of the user – both in research and in the application of knowledge. Although there are various factors that influence the collaboration process, it is the character and attitude of collaborative participants that is consistently stated as being important. Collaboration is a 'learning by doing' and dynamic environment where individuals' behaviour, feelings, attitudes, skills and understanding change over time. Participants involved in collaborations are exposed to learning about each other.

The 'gaps' in knowledge and relevant research questions that emerged from each aspect of industry-academia collaboration covered in this chapter (as shown in the last paragraph of each sub-section) are addressed in the next chapter (Chapter 3) where the formulation of a targeted research agenda is described.

3. Development of Research Questions & Methods

Chapter 2 has demonstrated the complex nature and increasing importance of industry-academia collaborative research. Key areas of concern for future study include the various factors that encourage cooperation, the diverse disciplines (both institutional and subject fields) that are involved, the motivations of the different participants, the barriers to collaboration and the numerous forms of interaction. The literature survey showed a need for further analysis of those factors that influence the effectiveness of collaborative research, in particular those related to the individuals who are involved in such collaborations, for example, their motivations for collaboration, their perspectives toward collaboration and the effect of their disciplinary backgrounds (professional & educational) on communication and knowledge transfer. This chapter uses the knowledge gained to both formulate a descriptive conceptual model of collaboration and specify a set of research questions for investigation. Both the conceptual model and the research questions reflect three key elements of industry-academia research collaboration. The model may be used as a descriptive framework or as a tool to help gain greater understanding of the nature of industry-academia collaborations. The last sections of this chapter then present the methodologies adopted for the research activities that were carried out to help answer the research questions.

3.1 Synthesis of themes & issues emergent from Chapter 2

In Chapter 2, it was concluded that the effectiveness of industry-academia collaboration depends significantly on the form of linkage mechanism and communication channels established, on the individuals involved (attitudes and characteristics) and also on how the relationship is managed. The type of interaction established mainly was seen to depend on the motivations and objectives of the various participants. In the literature it was demonstrated that industrialists and academics have different motivations and objectives based on their characteristics and organisational cultures. There are also variations between different sectors or fields as the nature of knowledge generation is different and there is considerable diversity in the techniques and methods adopted in different fields. Even though interdisciplinary collaboration is very valuable and has become increasingly common in recent years (as demonstrated in the bibliometric study described in Appendix 2A) the different objectives of the diverse participants can lead to complications and misunderstandings in collaborative research. In several recent studies, the 'different objectives' of the partners was found to be the most significant barrier in industry-academia relationships (e.g. Howells *et al.*, 1998).

It was also emphasised in the literature that free flowing two-way 'communication' is very important for successful collaboration. Communication is however, challenging where individuals come from different organisational cultures and disciplinary fields. The difficulties that may occur in communication include the different disciplinary or professional languages of the disparate participants, industry's concern for confidentiality versus an academic's preference for more promiscuous communication, and lack of clarity or feedback on issues related to the collaboration itself (e.g. objectives, findings, etc.). It is important to have good communication between the collaborative participants because it builds up understanding and trust, as well as contributing to the emergence of a joint language or vocabulary. Face-to-face communication can help the development of good personal relationships between individuals. The effectiveness of communication mainly depends on individuals' attitudes, behaviour, and capabilities. It is believed to be enhanced by the ability of individuals to be trusted (Dodgson, 2000) and to be facilitated by a common disciplinary background (Schartinger *et al.*, 2002).

The management of industry-academia collaboration is also problematic because it involves satisfying the interests and needs of participants from different organisational cultures, which have different motivations to cooperate. The management approach taken depends largely on the structure of the collaboration. For example, some (formal) collaborations require intellectual property rights and confidentiality agreements, some projects require flexibility for potential changes to the research direction, and collaborations may need procedures set up to accommodate personnel changes, etc. Other issues emergent from Chapter 2 include the roles of the participants, communication structure (e.g. for meetings, etc.), techniques for evaluating or monitoring the collaboration process, and funding. The recent transition from 'mode 1' to 'mode 2' knowledge production highlights the need for new ways of managing industry-academia relationships.

As it is impractical to address all the issues raised in Chapter 2, a selected number of themes will be studied. The themes that have been selected for this study are those which appear from the literature review to be significant in term of influencing successful collaboration. As a starting assumption on which to base the research, it is therefore suggested that the effectiveness of industry-academia collaborative research is at least partially dependent on the following three key elements:

- the 'Motivations & Objectives' for collaborative research;
- modes of 'Communication' between collaborative partners;
- the 'Management' of the collaborative processes.

3.2 Research questions

Based on the three key elements outlined above, a primary research question can be formulated as a basis for the research:

P1 *'What is the nature and extent of influence of barriers to effective industry-academia research collaboration in terms of (i) motivations and objectives, (ii) communication, and (iii) management?'*

For each of the three elements noted above, a secondary research question can be proposed as follows:

S1 *Are there differences in individuals' motivations for or perspectives towards collaboration in different sectors and how do these differences influence the effectiveness of collaboration?*

S2 *Do individuals' disciplinary backgrounds influence communication and knowledge transfer between collaborators?*

S3 *What are appropriate managerial or organisational strategies for effective industry-academia research collaboration?*

In question S2, the term 'disciplinary backgrounds' refers to the professional and educational backgrounds of the participants, including their job function and subject field, and their qualifications and skills. In question S3 'managerial or organisational strategies' refer to tactics used to manage the collaborative process (from the start to the end), for example, negotiation terms, model contracts or agreements, communication structure (meetings) and techniques for evaluating the collaborative process.

Answering the above questions will enable us to achieve the following representative outputs:

- Identify ways of balancing the competing objectives and sources of conflict within collaborating teams;
- Identify effective communication formats;
- Provide guidance on the management of industry-academia research collaborations.

3.3 Development of a conceptual model of industry-academia collaboration

Despite a thorough (and ongoing) search, no suitable conceptual model (i.e. one that is relevant to the three elements - motivations, communication & management) could be found in the literature that describes the characteristics of industry-academia research collaborations. A basic (simple) model to illustrate and explain the importance of the three key elements outlined in Section 3.1 for the effectiveness of industry-academia research collaboration is therefore proposed (Figure 3.1). The model is designed to provide a clearer descriptive view of the multifaceted nature of this topic and to support understanding of the factors that influence industry-academia collaborative research. Its development is based on knowledge gained from the research background in Chapter 2 and, along with the research questions, it will be used to help guide the research agenda. Comparing the research findings with the model will also enable us to test the model's applicability for studying industry-academia collaborations. We now turn to a description of the model's features.

In Section 3.1 it was suggested that management approaches depend on the 'structure' (see p.66 for further definition) of the collaboration which in turn is subject to the motivations and objectives of the participants. The participants' motivations and objectives are related to their attitudes and cultures (both individual and organisational). The success of the collaboration process, i.e. the "day to day" operation of collaborative research, relies on the management tactics as well as on the mode of communication (type, quality & frequency) between the participants (from the outset to the end). Communication is also influenced by the individuals' attitudes and backgrounds. The outcomes (e.g. benefits, products, knowledge, etc.) of the collaboration, whether negative or positive, can modify the participants' attitudes which in turn may either enhance or impede the collaborative process. Individuals involved in the collaboration process are also exposed to learning about each other and about working together which changes their understanding and skills, and therefore their attitudes. These interrelations are illustrated in the model shown in Figure 3.1. This model enables the industry-academia collaboration process to be viewed in a temporal aspect (i.e. as a set of cause and effect dynamics).

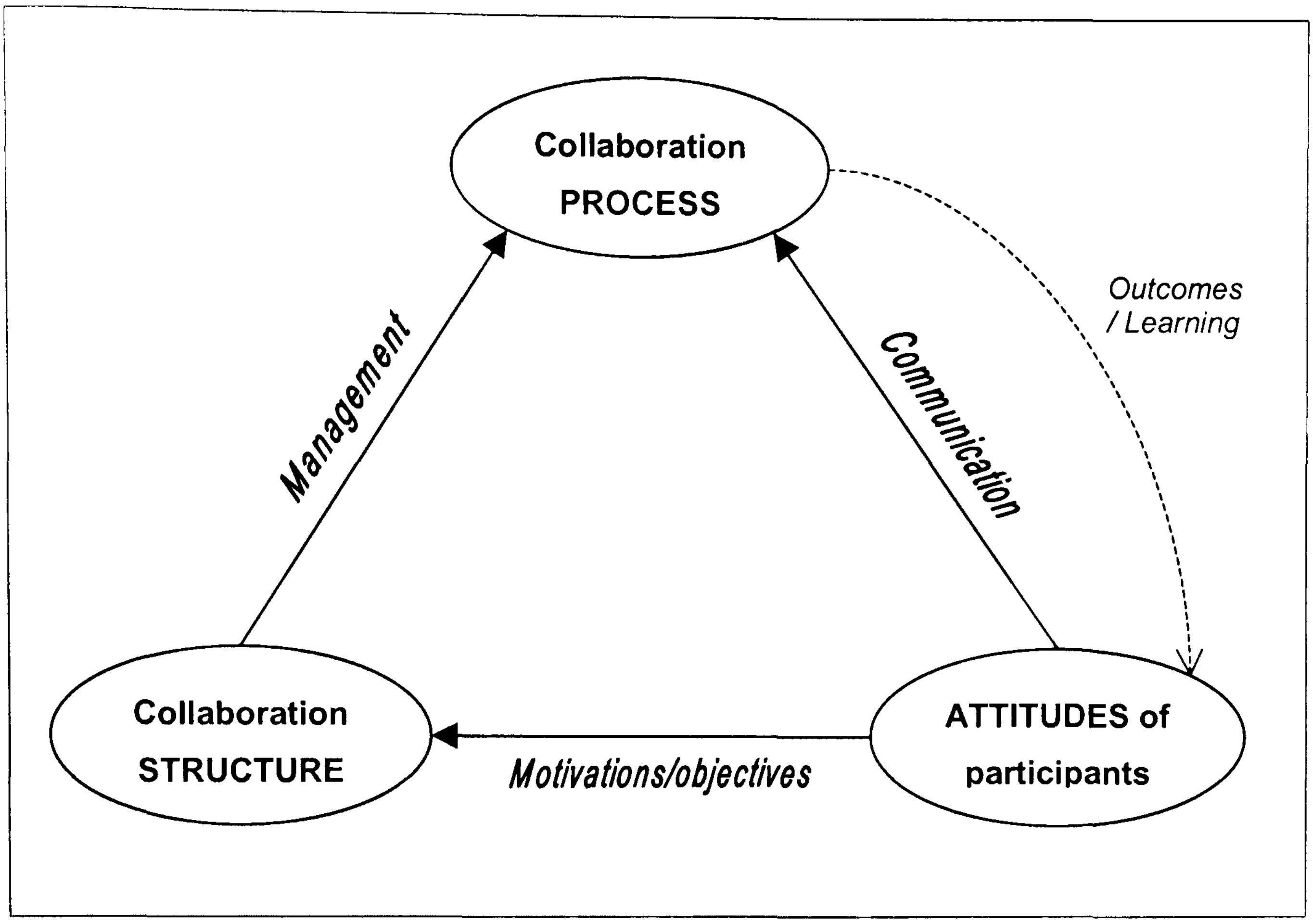

Figure 3.1: Conceptual model of Industry-Academia collaboration

The three collaboration 'characteristics' (ovals in model): i) collaboration structure, ii) attitudes of participants, and iii) collaboration process are described briefly in the following sub-sections with indications of what the research described in Chapters 4 and 5 will be investigating (based on the issues or 'gaps' in knowledge that emerged from Chapter 2). The development of the agenda for the fieldwork described in Chapters 4 and 5 will be discussed in more detail from Section 3.4 onwards.

i) Collaboration structure

Figure 3.2 presents the various factors that influence the 'structure' of collaboration. All the factors shown in Figure 3.2 can be seen as a function of the objective of the collaborative relationship, dependent on the motivations of the various participants. The research described in Chapters 4 and 5 will explore the nature of industry-academia collaborative research projects and networks in the UK, specifically to try and identify the characteristics of successful collaborative ventures in terms of their structure and the management and communication strategies adopted.

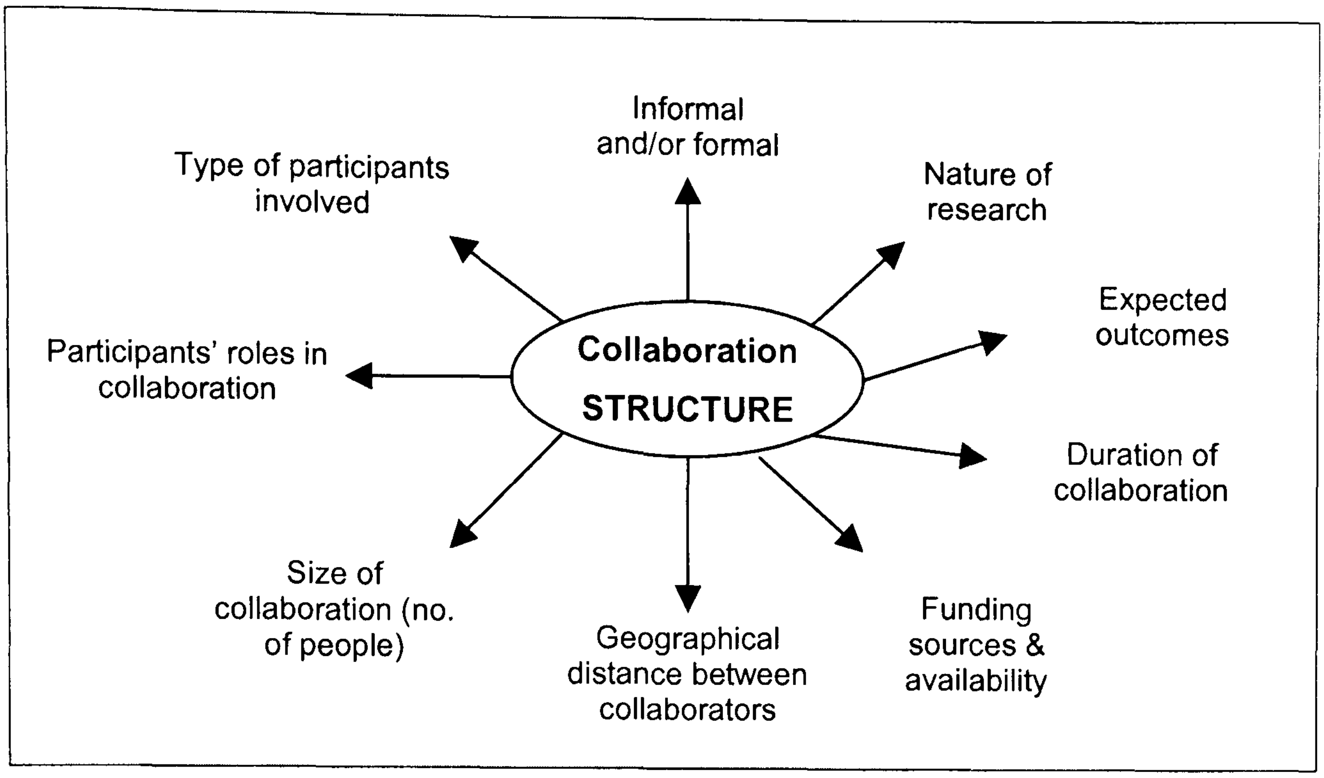

Figure 3.2: Elements of Collaboration Structure (developed by author)

ii) Attitudes of participants

The attitudes of collaborative participants are important because they influence the motivations and objectives of collaboration as well as the ability to communicate effectively and work with others in the relationship. As a result of their disciplinary backgrounds and organisational cultures, participants will have different attitudes to collaborative research and to each other. Some of the many factors that influence the participants' attitudes are listed both at the organisational and individual level in Table 3.1.

The research described in Chapters 4 and 5 will explore the influence of individuals' attitudes from various industrial sectors (e.g. science or craft-based) and academic fields on their motivations for and perspectives on collaboration and on their ability to communicate with other collaborative participants. It will investigate what the industrial and academic motivations are in the case of collaborative research projects and networks in the UK, and examine whether the different motivations of the various parties have an important influence on collaboration effectiveness. It will also explore the influence of different disciplinary backgrounds (professional & educational) of participants on communication in collaborative research. Variations in the nature (motivations, barriers, communication) of industry-academia research collaboration within different fields of research will also be analysed.

Table 3.1: Organisational & Institutional factors that influence attitudes (developed by author)

Organisational Level	***Individual Level***
Cultural aspects ▪ Mission & objectives ▪ Mode of operation & communication ▪ Priorities & timescales ▪ Information dissemination (IPR) ▪ Flexibility & adaptability	*Background of individual* ▪ Professional, educational & disciplinary. ▪ Learned behaviour & procedures ▪ Level of knowledge & expertise (of field) ▪ Prior collaboration experience ▪ Capabilities
Structure of organisation ▪ Size of R&D ▪ Disciplinary structure ▪ Capacities for knowledge exchange ▪ Research or Innovation performance	*Behavioural aspects* ▪ Commitment & willingness ▪ Flexibility & patience ▪ Understanding & awareness ▪ Trust & reputation

iii) Collaboration process

Collaboration is a dynamic process which changes over time and can be characterised using a variety of measures:

- The emergence of conflicts or unresolved issues between partners during the collaboration process and whether they are overcome;
- A build up, or a breakdown, of understanding (language), personal relationships, or trust during the collaboration;
- The balance of contribution from participants during the collaborative process;
- Generation of outcomes or achievement of objectives.

The research described in Chapters 4 and 5 will explore the process of collaboration, in particular the barriers or problems that occur as a function of differences in participants' objectives and perspectives, disciplinary backgrounds or behaviours, and communication. It will investigate what can or could be done to overcome these problems and also to maintain an effective collaborative process, for example appropriate management or communication strategies.

3.4 Development of the fieldwork agenda

This section introduces the development and design of the fieldwork carried out to explore the factors that influence the effectiveness of industry-academia collaborative research with the aim of answering the research questions outlined in Section 3.2. The literature review (Chapter 2) concluded that there is a lack of in-depth studies that investigate the cognitive or intellectual aspects of industry-academia collaborative research, in particular in the UK. Dodgson (2000) noted that studies of the factors that lead to success and failure in joint ventures are greatly needed, particularly to address the problems of differences in motivation for forming them, differences in approaches to their conduct and differences in assessment of their outcomes. The research design described below is informed by these observations. The research questions themselves demand an exploration of factors that influence the effectiveness of collaborative research, in particular those related to the three key elements that the questions are based on: (i) the motivations and objectives of the participants, (ii) communication between the participants and (iii) management of collaborative research.

3.4.1 How can the effectiveness of Industry-Academia collaborative research be explored?

Several authors have indicated that evaluation of the effectiveness of industry-academia relationships is problematic because there are significant differences in what constitutes 'success' and 'failure' in collaborations, principally due to the different expectations of the various participants. The success of any particular collaboration can be measured objectively via a number of outputs such as patents, publications, prototypes, etc. or by means of the relationship's progress over time or its continuity. It can also be measured subjectively in terms of the collaborative participants' perceptions, for example, their level of satisfaction (e.g. Lee, 2000). Examining and exploring perceptions is very difficult due to differences in individuals' beliefs, attitudes and behaviour. The perception of success or failure may be dissimilar for different individuals at distinct levels or functions within the collaborating organisations (e.g. senior managers, researchers, students). It is however believed that analysing the perceptions of collaborative participants is the most practical measurement approach because of the complex nature of collaborations in terms of different objectives, temporal changes, as well as sectoral variations. In their study, Barnes *et al.* (2002) placed emphasis on the perceptions of participants because it is believed that collaborative ventures are often perceived as failures despite the generation of significant technological or other tangible outcomes and that such perceptions may influence individuals' decision to collaborate in future. Also, because collaboration is a dynamic process, it is believed that temporal features, e.g. changes in attitudes, build up or breakdown of communication, etc. (as described in the model in Section 3.3) can be explored more clearly through individual perspectives. Obtaining and exploring individuals' reflections of what was intended to happen, and what has happened (or is happening) over time, will provide greater understanding of the collaborative research process and this strategy was chosen as an effective way to obtain and evaluate the perspectives of individuals who are involved in or with industry-academia collaborative research. The options available for eliciting the perceptions of such individuals are to engage them through either interviews or questionnaires. The following section describes how the response groups for the surveys were selected and Section 3.4.3 discusses elicitation techniques.

3.4.2 Selection of response groups

The type of information sought to answer the research questions outlined in Section 3.2 requires the reflection of individuals on their experience of industry-academia collaborative research, particularly those who have recently been or are involved in such collaborations. Two response groups were selected for the surveys: (i) collaborative research facilitators and (ii) students involved in collaborative projects for the following reasons (& as informed by the model described in Section 3.3):

(i) The collaborative research facilitators can provide information on both the 'structure' of the collaborative networks or projects that they support and the 'attitudes' of participants involved in such collaborations. They can also provide information on the planning aspect of collaboration and a 'theoretical' point of view on collaborative research (i.e. what should happen).

(ii) The students can provide information on both the collaboration 'process' and the 'attitudes' of collaborative participants. They can also provide information on the implementation of collaboration and a 'coal-face' point of view of collaborative research (i.e. what does happen).

The other obvious population to access would have been the student's academic supervisors and industrial contacts, who are, after all, the primary points of collaborative contact. This group were not surveyed for the following reasons:

i) A good response rate to a survey is unlikely from this group;
ii) They may have entrenched perspectives, i.e. they are likely to provide a 'corporate' view;
iii) They rarely have day-to-day experience of the collaboration because they have many other tasks – it is the students who do the actual work;
iv) Access to this group would be difficult - in particular the industrial contacts as their details are not available on the central registers of EngD and CASE awards provided by the Research Councils.

Evaluating the perspectives of the collaborative research facilitators and the students enables comparisons to be made of the perceptions of individuals who are involved at different levels or functions of collaborative research, i.e. the experiential responses from the students will be compared with the largely theoretical views of the research facilitators. The collaborative research facilitator survey is therefore carried out first and the design of the student survey is based on the findings of the first survey (as well as the research questions). Another reason for surveying the collaborative research facilitators first is because they have more experience of collaborative research and therefore they may help extend or focus the research agenda and also help us avoid asking irrelevant or misplaced questions in the second survey.

In the UK, many (formal) industry-academia collaborative research projects or networks are organised and supported by government agencies such as the

Research Councils and the Office of Science and Technology (OST). Many collaborative relationships are also managed by corporate liaison offices based at universities. These 'collaborative research facilitators' can provide information concerning both sides of the collaborative relationship (industry & academia), as well as on themselves and on the effectiveness of current schemes that fund or support collaborative research. The process of selecting and accessing these respondents is further described in Section 4.2.2 (Chapter 4). They were carefully selected for their particular expertise or experience of facilitating or managing the 'process' of industry-academia collaboration. They engage in bringing the parties together and in some cases, monitor the relationship. They were also chosen from as diverse a range of organisations as possible, i.e. from different research councils and from industrial liaison offices based at different universities (both traditional and technical), to allow a comparative analysis to be carried out.

Recently there has been increasing awareness in the literature of the role of students who are involved in collaborative research, but to date no specific studies have been carried out that focus on their experience or perceptions of such research. Barnes *et al.* (2002) point out that their involvement is important because the academic objectives of universities favour the inclusion of students in collaborative projects. In their study of six collaborative research projects, they found that the effects of differences in the priorities and perspectives of academia and industry were clearly evident from the experiences of doctorate students involved in the projects. They concluded that it would be in the interest of both industrial partners and students to establish guidelines for their deployment in such projects. In the UK, collaborative research schemes that involve students include the CASE (Collaborative Awards in Science and Engineering) and Engineering Doctorate (EngD) schemes which are funded by both research councils and industrial sponsors. They provide students with experience of both academic (curiosity driven, blue-skies) and industrial (applied & strategic) motivated research. These research students experience both sides of the collaborative venture (e.g. industry and academia). Evaluating their perspectives of collaborative research will therefore provide information on many important interface issues as well as on their own experiences.

3.4.3 Selection of elicitation techniques for the response groups

Once the response groups for the surveys were selected, a choice had to be made on which elicitation technique to use for each group. This section outlines and compares the different research methods available for eliciting individual perspectives and Section 3.5 describes the research design chosen for this research.

There is considerable literature on various types of elicitation techniques (both qualitative and quantitative) as well as on the philosophical, theoretical and methodological issues associated with each method. In general, qualitative methods provide meanings and descriptions of personal significance and quantitative methods provide quantities and level of statistical significance (Silverman, 2000). Table 3.2 outlines a range of methods that can be used to elicit individual perspectives and their advantages and disadvantages. The method used mainly depends on the purposes and goals of the research being carried out. The choice of method is also influenced by their feasibility within the constraints of available time and resources (Robson, 2002). For example, in participant observation it takes time to be fully involved in a group, whereas methods like questionnaires are a rapid and economical means of collecting data about a population. Observational methods are time consuming also because they require disciplined training and careful preparation (Patton, 1990). For methods like documentary analysis and secondary data analysis, valid information needs to be readily available. Records of participants' perceptions on collaborative research are however not readily available.

Table 3.2: Elicitation methods & their advantages & disadvantages

Method	*Description*	*Advantages*	*Disadvantages*	*References*
Naturalistic observation (ethnography)	Observing & recording naturally occurring behaviour (talk, feelings, etc.) in natural settings	Subjects do not know they are being observed therefore researcher can be confident that behaviours are natural	Researcher does not have much control over what happens. Highly subjective method using one's own perceptions/biases to describe observations. Unethical.	Martin & Bateson (1986) Patton (1990)
Participant observation	Researcher becomes involved in the life activities of a group of people & records their observations & experiences	Allows the researcher to engage in open-ended exploration	Observations are difficult to generalise to other situations. Researcher's presence can alter people's behaviour. Can take time to be fully involved in group.	Patton (1990) Spradley (1980) Bogdewic (1999) Lofland & Lofland (1995) Robson (2002)
Documentary analysis (content analysis)	Analysis of & drawing conclusions from existing documents, records or reports (data recorded without intervention of researcher)	Can study large populations & naturally occurring trends over time.	Subject to biases of interpretation. Researcher cannot control data collection.	Weber (1990) Neuendorf (2002)
Secondary data analysis	Re-analysis of existing survey data collected by someone else for a different purpose.	Huge savings in time & effort by avoiding collection of new data.	Lack of control over what information was collected & how it was collected.	Hakim (1982)
Case study	In-depth/empirical study of one particular organisation/event	Allows thorough examination of a particular situation.	Results cannot be generalised beyond single case.	Yin (1989) Robson (2002)
Surveys & questionnaires	Obtain individual characteristics, attitudes, & thoughts by asking them a set of prepared questions.	Allows comparisons between different individuals. Economical means of collecting data about a population.	Depends on participant's ability to truthfully & accurately answer the questions. Subject to bias, both respondent & researcher.	Doyle (2001) Robson (2002) Oppenheim (1992)
Personal interviews (& focus groups)	Face-to-face questioning of people selected for their particular knowledge. In focus groups, several people are interviewed together.	Allows an exploratory approach through use of open-ended questions.	Subject to bias, both respondent & researcher. Can be time-consuming, particularly if unstructured.	Fontana & Frey (2000) Robson (2002)

Therefore, as stated in Section 3.4.2, the most suitable options available for eliciting the perceptions of collaborative research facilitators and students involved in collaborative projects are to engage them through either an interview or questionnaire activity. Interviews, questionnaires or attitude scales are the most appropriate methods for finding out what people think, feel and/or believe (Oppenheim, 1992; Robson, 2002). Although interviews and questionnaires both have strengths in their ability to obtain individuals' perspectives; they both have limitations as well; these are outlined in Table 3.3.

Table 3.3: Advantages & limitations of interviews & questionnaires

Interviews	*Questionnaires*
▪ Considerable amount of time, effort & skills required to design, carry out & analyse interviews (need good understanding of topic being studied) ▪ Only a limited number of people can be interviewed because of time constraints ▪ Interviewer needs a variety of skills including interpersonal skills. ▪ Interviewer's behaviour or presence may alter respondents' thoughts & behaviours (may bias results of study). ▪ Interviews represent 'off-the-top-of-the-head' thoughts of people who have limited time to think about their answers.	▪ Time & skills required to design (& pilot) questionnaire. ▪ Need to assume that perceptions or beliefs are described or measured accurately through self report (& honesty of responses). ▪ Misunderstandings (of questions or answers) cannot be checked immediately.

Face-to-face interviews allow both parties to explore the meaning of questions and answers involved, therefore misunderstandings by either the interviewer or the interviewee can be checked immediately (Robson, 2002). They also have the advantage of providing rapid and immediate responses. The main disadvantage of interviews however, is that they are resource-intensive and time consuming. Therefore sample sizes will be smaller and it may be more difficult to generalise findings. Interviews are generally best suited to exploratory studies which aim to obtain rich, in-depth information on individuals' experiences and perspectives, while questionnaires are better for testing hypotheses or theoretical propositions via the use of objective measures. Doyle (2001) states that personal interviews are best where detailed, narrative information is required and that simple factual information or quantitative judgements can be collected much more efficiently and accurately through questionnaire surveys.

Given these limitations it was deemed appropriate to elicit the perspectives of the collaborative research facilitators through face-to-face interviews, and the student's perceptions via a questionnaire survey which enables us to test the influence of issues that emerged from the interviews and the literature review, via mainly quantitative measures. There are many collaborative research projects (e.g. CASE & EngD) that involve students which are funded by different industrial organisations and research councils. Obtaining the perspectives of students carrying out collaborative projects in a diverse range of fields enables comparative or cross-sectional analysis of experiences in different sectors or fields. This is important as the literature survey in Chapter 2 showed that there are various approaches to collaborative research within different organisations and different fields of research. Because interviews are time-consuming to conduct and analyse, only a limited number of collaborative research facilitators can be interviewed. The sample size however needs to be sufficiently large enough to allow comparison and to extrapolate themes and concepts (Gilbert, 1995). Therefore a decision was made to interview a sample of approximately 20-30 people (see Section 4.2.2). The next section describes in more detail the proposed methods of collecting the information required from these two response groups and of analysing the data.

3.5 Design of data collection & analysis methods

In the previous section it was indicated that the perspectives of industry-academia collaborative research facilitators would be obtained through an interview survey and those of students who are involved in collaborative projects by means of a questionnaire survey. Figure 3.3 relates queries related to the research questions listed in Section 3.2 (S1, S2 & S3) to the type of information required from the respondents, the proposed methods and representative outputs.

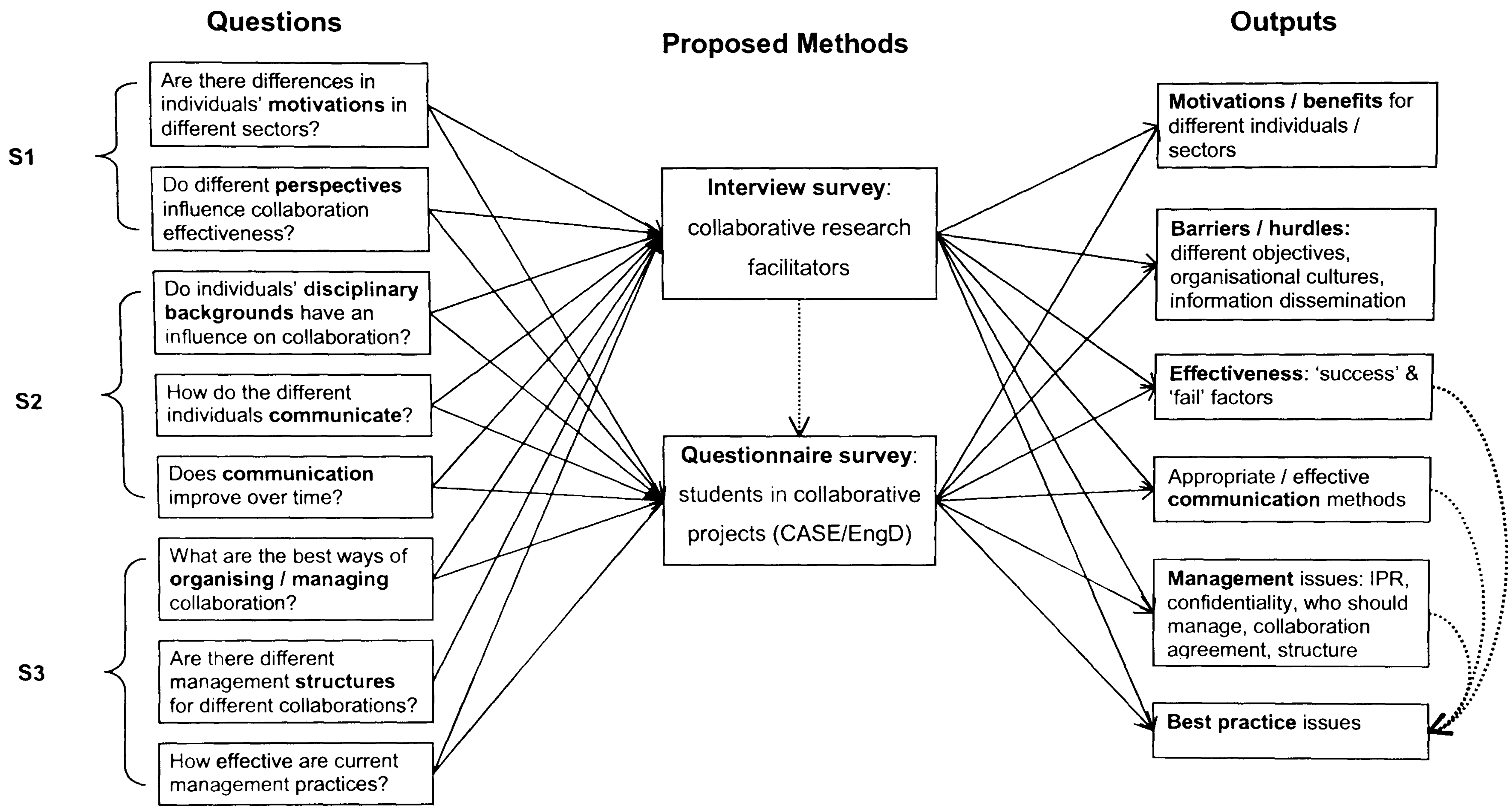

Figure 3.3: Research questions, methods & outputs

There are a variety of qualitative and quantitative measures that can be employed to analyse individual perspectives dependent on the chosen method of data collection. For example, theme or pattern identification in qualitative data (Ryan & Bernard, 2003; Miles & Huberman, 1994), and level of satisfaction or importance based on scales, scores, or frequencies in quantitative data (Robson, 2002; Foddy, 1993). There are also two different models for data collection and analysis: i) data is collected and then analysed, or ii) data collection and analysis can happen simultaneously (Robson, 2002). The next sub-section describes the approach chosen for the interview survey and in sub-section 3.5.2 the questionnaire survey method is discussed.

3.5.1 Interview survey method

There are three versions of interviews which differ in degree of structure and formality: i) structured, ii) semi-structured, and iii) unstructured (Robson, 2002; Yin, 1989; Fontana & Frey, 2000). In a fully structured interview, the interviewer asks the respondents a series of pre-established questions (in set order) and provides them a limited set of response categories. One benefit of this method is that it is easy to compare responses between different respondents. This method however does not allow exploration of topics of interest. In a semi-structured interview, the researcher uses a set of pre-prepared questions but the order in which the questions are asked is determined by the interviewer and the questions can be adapted depending on the interviewee's responses. The disadvantages of this technique are that the researcher needs to be well prepared and trained, and that more time is needed for data analysis compared to structured interviews. In an unstructured interview, the researcher does not have a pre-established set of questions in hand. The benefit of such interviews is that a wealth of data is obtained from the respondent but there is a risk of obtaining irrelevant information due to the lack of structure. It is also difficult to compare unstructured interviews with each other because the questions and responses are slightly different.

For the interview survey, a semi-structured interview technique was adopted as it offers the following advantages as a method of data collection:

- It obtains relevant information as the interviewer has the freedom to explore topics of interest, general views or opinions, in more detail;
- It allows the interviewees to talk around a topic, express their opinions, concerns and feelings whilst keeping content to specific themes;
- It is structured so as to allow comparisons between the interviewees' responses on particular topics.

A semi-structured format ensures that respondents focus on the key themes that the research questions are related to; in this case, motivations, communication, management, and best practice. This method is preferred to the structured technique which does not facilitate open discussion and therefore does not explore interviewees' reasons for their views or feelings about the issues. When carrying out qualitative interviews, it is easy to look for the "average" experience (Lee, 2000), so to avoid the tendency of the respondent to provide a general impression, it is appropriate to ask them to refer to specific examples of collaborative research.

As the design of the questionnaire template for the students is partly based on key issues or findings that have emerged from the interview survey (so that comparisons can be made of the perceptions of the two disparate groups of respondents), the chosen technique for analysing the interview data has to be relatively quick so as to allow enough time to design and carry out the questionnaire survey of students. The choice of analysis approach also depends on the research questions, on what is already known about the topic of interest and on the method of data collection (Robson, 2002). Possible approaches to analysing qualitative data are very diverse. As Crabtree & Miller (1992) point out, "nearly as many analysis strategies exist as qualitative researchers" (p.17) because qualitative analysis requires the creative involvement of the researcher. Several authors have developed categorisations of methods to assist discussions of analysis (Tesch, 1990; Crabtree & Miller, 1992). Tesch (1990) identified 46 different methods described by qualitative researchers and summarised them into four basic categories; these are shown in Table 3.4 which also shows examples of methods corresponding to each category (for further information on each method, see references in Table 3.4).

Table 3.4: Qualitative data analysis methods

Category	Examples of methods & references
Characteristics of language	Communication - e.g. conversation/discourse analysis (Have, 1999; van Dijk, 1985) Analysis of language in cultural context – e.g. structural ethnography (Spradley. 1980)
Discovering regularities	Identification (& categorisation) of elements & exploration of their connections – e.g. grounded theory (Strauss, 1987); logical/matrix analysis (Miles & Huberman, 1994) Identification of patterns - e.g., typologies (Lofland & Lofland, 1995)
Understanding meaning of text or actions	Theme discovering – e.g. phenomenological analysis (Moustakas, 1994) Interpretation centred – e.g. hermeneutics (Bentz & Shapiro, 1998)
Reflection	Metaphorical analysis (Patton, 1990)

The main objective of the research in this thesis is to identify factors influencing collaborative research based on individuals' perspectives, therefore the identification of key elements in the data is the most appropriate approach to analysing the interview data. Theme identification is one of the most fundamental tasks in qualitative research. Compared to an in-depth or informal interview technique, the semi-structured interview format better facilitates the identification and categorisation of themes in interview transcripts. There are a variety of techniques for discovering themes in texts ranging from quick word counts to laborious, in-depth, line-by-line scrutiny, as follows (from Ryan & Bernard, 2003):

- Analysis of words: e.g. word repetitions, key-indigenous terms & key-words in contexts;
- Careful reading of larger blocks of texts: e.g. compare & contrast, social science queries, searching for missing information;
- Intentional analysis of linguistic features: e.g. metaphors, transitions & connectors;
- Physical manipulation of texts: e.g. unmarked texts, pawing, & cut and sort procedures.

In general, the choice of technique depends on the type and amount of text, the experience of the researcher and the goals of the project. Word-based techniques are quick (less labour intensive), versatile and efficient ways of identifying themes and are especially useful at early stages of analysis. However, according to Ryan & Bernard (2003), nothing beats scrutiny-based techniques which are more time-intensive and require a lot of attention to details and nuances. They highly recommend thorough reading (several times) and 'pawing through' texts, marking them up with different coloured pens to highlight key phrases, in the early stages of exploration. This approach is simple for novice researchers to master and is particularly good for identifying major themes. Cutting and sorting is a more formal way of pawing and is particularly useful for identifying sub-themes. The text is read through and quotes that seem somehow important are identified and sorted (cut & pasted) into piles (representing themes) of similar quotes. This technique is useful for describing how the themes are distributed across informants. Texts representing major themes can be marked either on paper or by computer and then cut and sorted into sub-themes. Ryan & Bernard (2003) state that an even more powerful strategy is to combine multiple techniques in a sequential manner, for example, to begin by pawing through the data to see what kinds of themes emerge and as part of this process, make comparisons across informants. A quick analysis of word repetitions would also be appropriate for identifying themes at this early stage of analysis.

Miles & Huberman (1994) describe qualitative data analysis as consisting of three concurrent flows of activity: data reduction, data display, and conclusion drawing and verification. Data reduction is the process of selecting, focussing, simplifying, abstracting and transforming data in transcriptions. It is the part of data analysis that sharpens, sorts, focuses, discards and organises data so that "final" conclusions can be drawn or verified. Recording and transcribing interviews results in an unwieldy amount of verbal data so reducing the amount of data to a more manageable level is one of the main tasks of qualitative data analysis (Doyle, 2001). The next activity, data "display" involves organised and compressed assembly of information that permits conclusion drawing and action. Examples of displays include matrices, graphs, charts and networks which are all designed to assemble organised information into an immediately accessible, compact form so that analysts can see what is what is happening and either draw justified conclusions or move on to the next step of analysis. Displaying reduced data in a systematic way involves having to think about the research questions and what portions of data are needed to answer them, thus it is necessary to carry out full analysis of the data, ignoring no relevant information, and to focus and organise information coherently (Miles & Huberman, 1994). Conclusion drawing involves stepping back to consider what the analysed data mean and to assess their implications for the questions at hand. When qualitative data are used as a precursor to the design or development of quantitative instruments (e.g. questionnaires), this step may be postponed - data reduction and looking for relationships will provide enough information for developing such instruments (Berkowitz, 1997). Verification, integrally linked to conclusion drawing, entails revisiting the data as many times as necessary to cross-check or verify the emergent conclusions.

The multiple-technique approach, as recommended by Ryan & Bernard (2003), has been applied to the interview survey data. First the interview transcripts were read carefully several times, highlighting key passages of text at the same time. Codes were then applied to each marked passage indicating which theme it relates to (using a word processor). 'Open' coding is a common process where passages of text are named and categorised using alphanumeric codes through close examination of the data (Miles & Huberman, 1994). The data was then 'reduced' by cutting and sorting (pasting) the passages into thematic tables ('data displays'), enabling cross-case analysis to be carried out. The thematic tables can be split into rows representing sub-themes identified in the text. The 7-stage approach adopted for analysing the interview data is summarised as follows:

1. Transcribe taped interviews using a word processor.
2. Read through each interview transcript carefully (several times); identify and highlight most important, meaningful and interesting parts

of interview text, using the themes that the interview questions are based on as a guide (determined by research questions in Section 3.2).

3. 'Open coding' - classifying and categorising key passages of transcripts: assign each coherent interview segment a code to indicate the concept, category or theme it relates to.
4. Copy and paste segments together thematically to serve as raw material for analysis of the survey responses.
5. Display data as cross case analysis tables (in Word): group together appropriate responses from each interviewee into tables corresponding to each theme, make comparisons across individuals and identify similarities, differences, patterns and thematic connections in interview data.
6. Identify sub-themes within each thematic table and create rows of data corresponding to each sub-theme.
7. Carry out quasi-statistics: count number of times something is mentioned in data as a rough estimate of frequency (e.g. no. of interviewees that express a particular concern or who shared a similar experience).

The tabular structures built for each survey theme provide a basis for writing a narrative on the output of the interview activity; for example, what was the variation in opinions about issue X or did everyone have a similar response. This approach is quite similar to that taken by Barnes *et al.* (2002) who tabulated influential success factors that emerged from each individual case together (six case projects) so that comparisons could be made and patterns of similar factors could be identified. This formed the basis for a detailed evaluation of the case study evidence so as to establish the background and circumstances behind the major factors that emerged. The analysis process employed in sorting, analysing and making sense of the interview data is described further in Chapter 4, Section 4.2.2.

3.5.2 Questionnaire survey method

There are many different forms of questionnaire surveys with a wide range of purposes but there are a few common characteristics (Robson, 2002). Generally standardised questions are used to collect information so that all respondents in the survey population answer the same questions and their responses can easily be compared. The design and construction of questionnaires has been characterised as a predominantly subjective process that is largely guided by the experience of the designer (Goodman, 2003). Thought must be given at the design stage as to how responses will be analysed (DPRM, 1999). As stated earlier, the design of the questionnaire template for the student survey is based on key issues or findings that have emerged from the interview survey as well as the research questions.

When designing a questionnaire template, a choice has to be made on what type of questions should be used. There are two basic 'species' of question, 'open' and 'closed'. Open questions allow respondents to answer in their own words and closed questions give the respondents a finite (usually small) number of choices from which they can select one or more. In his detailed account of the advantages and disadvantages of 'open' and 'closed' questions, Foddy (1993) summarised the most important claims that have been made (in the literature) regarding the two formats – see Table 3.5. According to Foddy (1993), it is not clear which format produces the most valid responses as open and closed versions of the same questions have been found to typically generate quite different response distributions. He argues that '*unless respondents have a clear understanding if what the question is about and are told what perspective to adopt when framing an answer, different respondents will answer the same question in quite different ways*' (applies to both closed & open questions; p. 150).

Table 3.5: The most important claims that have been made regarding open and closed questions (from Foddy, 1993).

Open questions	*Closed questions*
(a) Allow respondents to express themselves in their own words. (b) Do not suggest answers - indicate respondent's level of information - indicate what is salient in the respondent's mind - indicate strength of respondent's feelings. (c) Avoid format effects. (d) Allow complex motivational influences and frames of reference to be identified. (e) Are a necessary prerequisite for the proper development of sets of response options for closed questions. (f) Aid in the interpretation of deviant responses to closed questions.	(a) Allow respondents to answer the *same* question so that answers can be meaningfully compared. (b) Produce less variable answers. (c) Present a recognition, as opposed to a recall, task to respondents and for this reason respondents find them much easier to answer. (d) Produce answers that are much easier to computerise and analyse.

It is believed that a careful mix of open and closed questions is best and also that qualitative, in-depth interviews should precede the formulation of fixed-choice questions so that response categories will reflect the respondents' worlds rather than the researchers'. This is the approach that is adopted here with the interviews with the collaborative research facilitators preceding the student survey. There are numerous 'varieties' of closed questions, each providing different types of data. Table 3.6 provides a list of seven different types of questions and their expected response and advantages or disadvantages (source DPRM, 1999). As a general rule of thumb, the more structured a question, the easier it is to analyse. Because of the large number of responses expected from the student survey, it was more appropriate to include mostly closed-type questions in the questionnaire template to facilitate subsequent analysis of the responses. A few open-ended questions or spaces are also included to allow respondents to add comments in their own words.

Table 3.6: Different types of questions (from DPRM, 1999)

Type	*Expected response and advantages/disadvantages*
Open	Sets of general comments. May produce useful information, but difficult to analyse.
List	List of items offered; respondent ticks/rings chosen responses. Easier to analyse, but provides less detailed information.
Category	Given sets of information, e.g. age: under 20; 20-29; 30-39; etc. More acceptable to interviewees (especially when used for financial data). Easier to group respondents when analysing data.
Ranking	Respondent places given sets of data in order of performance. Particularly useful when one objective of the survey is to evaluate the respondents' perception of different scenarios.
Response	E.g. Excellent; Very good; Good; Average; Below average; Poor.
Scale	Broad categories of evaluation are sufficient.
Quantity	Respondents are asked to score an issue on a numeric scale/provide estimates or data in a quantitative manner. Provides more precise quantitative data.
Grid	Used to provide a response to two or more questions at the same time. Saves space, speeds up questionnaire completion and aids analysis.

Many of the questions used in the student survey measure their 'attitudes' to specific issues. There are many question devices that can measure respondents' 'attitudes' – a detailed list of the most commonly used techniques is provided by Foddy (1993). The different techniques are classified into 'ranking' devices and 'rating' procedures. Ranking devices provide information about the order in which each respondent would place items. However, these do not indicate the subjective importance or weight each respondent would assign to each item and therefore the different respondents' rankings cannot be sensibly compared. On the other hand, rating procedures (e.g. Likert scales) can provide rough information about the perceived significance of each item classified into a small number of categories (usually 3 to 7). However, this type of procedure fails to give clear information about the relative importance of the items to the respondents. Rating scales are a very popular measurement procedure possibly due to the fact that they appear easy to prepare and that respondents seem to find them easy to use (Robson, 2002; Foddy, 1993). Foddy (1993) also emphasises that, as with all other types of questions, these rating scales need to satisfy three basic considerations:

v) the topic of focus should be clearly defined;
vi) the relevance of the topic to the respondents should be established;
vii) respondents should all give the same kinds of answers.

When choosing appropriate wording for questions, the following issues need to be avoided: ambiguity, imprecision, assumption, presumption and leading the respondent (DPRM, 1999; Robson, 2002). The questionnaire used in this research was piloted on a few students prior to the main survey to ensure that the students understand the questions and provide the required form of responses. Piloting the questionnaire provides an opportunity for the researcher to remove any questions that provide unwanted or irrelevant information, rewrite any questions that are ambiguous, offensive, etc. and redesign any questions that provide information in an unhelpful manner (e.g. not precisely enough) (Oppenheim, 1992).

There are two main approaches to analysing quantitative data – exploratory and confirmatory (Robson, 2002). Exploring the data involves describing the basic features of the data, for example, frequency distributions and graphical displays, and summary or descriptive statistics. Inferential methods are ways of reaching conclusions that extend beyond the data, for example, tests of statistical significance (t-test). The relationships between variables in a data set can be analysed through a wide variety of methods including cross tabulations, correlation coefficients and multiple regression dependent on the number of variables being examined (e.g. univariate, bivariate, multivariate) and the levels of measurement being used (i.e. nominal, ordinal, interval, or ratio). The quantitative data from the questionnaire survey are analysed using SPSS (Statistical Package for Social Sciences) which enable descriptive frequencies to be carried out as well as a number of other statistical procedures such as t-tests. Simple content analysis techniques, for example, quasi-statistics, are used on answers to the open-ended questions. Quasi-statistics involves the conversion of qualitative data into quantitative format by establishing a set of categories and then counting the number of instances that fall into each category. The techniques used in analysing the questionnaire survey data is further described in Section 5.2.3, Chapter 5.

3.6 Summary

In this chapter the research questions which underpin the study to be carried out were introduced. They are based on three key elements that emerged from the research background presented in Chapter 2 and which appear from the literature review to be significant in term of influencing successful industry-academia collaboration: (i) motivations and objectives; (ii) communication; and (iii) management. A simple conceptual model was created to illustrate the importance of these three key elements to industry-academia collaboration. The key elements are shown to be dependent on the attitudes and characteristics of collaborative participants, the structure of the collaboration, and the collaboration process and its outcomes. The model enables us to view collaborative research as a dynamic, not a static, process (i.e. one that changes over time in terms of cause and effect dynamics). It may be used as a tool or as a descriptive framework for exploring industry-academia relationships and to help gain greater understanding of this topic.

The last section (3.6) of this chapter described the design and development of the two fieldwork activities which generate the data used to answer the research questions. These two surveys are described in the next two chapters (4 & 5). The type of study chosen is a comparative and cross-sectional study with information primarily obtained from the perspectives of participants involved in or with industry-academia collaborative research. The perceptions of collaborative research facilitators are obtained through semi-structured interviews and the perceptions of students who are involved in collaborative projects through a questionnaire survey. A number of approaches to data analysis were explored resulting in a decision to use both qualitative and quantitative research techniques on the data obtained from the fieldwork.

4. Research Activity - Interview survey of collaborative research facilitators

This chapter is the first of two chapters which describe the fieldwork activities carried out to explore the key issues related to the research questions (outlined in Chapter 3) with the ultimate aim of identifying ways of improving the effectiveness of research collaboration between industrialists and academics. The previous chapter provided a justification for the chosen research approach: how the information was collected, which response groups were to be accessed, and tactics for analysing the obtained data. The general objective of the fieldwork was to obtain and analyse individual reflections on and perceptions of their experience of industry-academia collaborative research. In this chapter the activities and results of the interviews carried out with industry-academia collaborative research facilitators are described.

Prior to interviewing the collaborative research facilitators, a pilot or 'scoping' interview was carried out to test and evaluate the robustness of the proposed data collection approach. The information that emerged from the scoping interview as well as the research background reported in Chapters 2 and 3 supported the design and structure of the questions for the main interview survey. The pilot study is described briefly in the next section (4.1). The following section (4.2) describes the design and deployment of the main survey itself and includes details of the development of an interview template (questions), how the participants were selected, logistical and ethical considerations as well as the analysis techniques used on the data obtained. The results of the interviews are presented in Section 4.3, with a brief summary of the findings given in the last sub-section. As indicated in Chapter 3, the findings of the interviews were taken into account when designing the second fieldwork activity which involves a questionnaire survey of students involved in collaborative research projects (Chapter 5).

4.1 Scoping interview

In order to overcome uncertainties about exploring individuals' perspectives on industry-academia collaborative research, particularly on the topics of interest as defined by the research questions (listed in Chapter 3), a 'scoping' or pilot interview was conducted to both test out some of the proposed approaches to data collection and to help design the questions for the main interview survey. It is important to interview individuals who can present "the big picture" at the start of an interview based study so that all of the important sub-topics can be identified (Doyle, 2001). Before pursuing the fieldwork, there is a need to gain a 'feel' and an understanding of the subject, otherwise the planning and design is constrained (Oppenheim, 1992; Robson, 2002). The scoping interview offers the interviewer the opportunity to develop understanding and familiarity with the area of study and is useful for developing and refining the approach to be taken for the main study. It enables us to find the best method of collecting data to achieve answers that are pertinent to the research questions. As Foddy (1993) points out, the interviewer should know precisely what questions to ask, based on the type of information that is sought.

The scoping interview was carried out in May 2002 with an individual with extensive experience of research and development (R&D) management in large companies within the water and chemical industries and of industry-academia collaborative research networks. The individual was involved in the management of an EPSRC funded network based at the School of Water Sciences at Cranfield University. He was contacted informally and asked if he would agree to be interviewed. The final arrangements for the interview were established by email. Prior to the interview, a list of topics to be covered in the interview was devised based on the research questions as well as the knowledge gained from the literature review. These were classified under the following headings:

- Motivations for industry-academia collaboration;
- Barriers to effective industry-academia relationships;

- Communication within industry-academia collaborative networks;
- Management of collaborative projects and networks;
- Measures of collaboration effectiveness or success.

Before responding to questions related to these topics, the interviewee was first asked to provide information on his professional background and his experience of industry-academia interactions. The last topic listed above is not directly related to the research questions outlined in Chapter 3 but it was believed that this issue should also be covered in the interviews because, as indicated in the literature review, different institutions have diverse preferences for defining and measuring collaboration success or effectiveness. The face-to-face interview was administered by an interviewer and recorded using a digital voice recorder. The interview took place in a small room (to avoid background noises) at Cranfield University and lasted for an hour and 8 minutes. The voice file was downloaded to a computer and transcribed using a word processor. The transcript was carefully read several times and the passages of text that were directly relevant to the research themes were underlined. Comment balloons were added alongside each highlighted segment (using the 'reviewing' toolbar in Word) with keywords and brief descriptions of what the passage refers to. Reviewing all the comments led to the development of a list of key issues that emerged from the interview; this is presented as Table 4.1.

Several of the issues raised during the scoping interview echo the findings from the literature review (Chapter 2) including:

- barriers often result from the different cultures and working practices of industry and academia (timescales, expectations & language);
- the agreement of IPR can be problematic;
- the importance of understanding for developing trust;
- there are difficulties in defining and measuring effectiveness or success in industry-academia collaborations.

Table 4.1: Key issues emergent from the Scoping Interview

Issue	***Interviewee comment***
Timescales	There is a conflict between industrial and academic timescales in collaboration.
Willingness	The willingness of the participants to modify working practices (i.e. work to different schedules) helps collaboration.
Measures	There are various measures of effectiveness or success, both objective and subjective. Subjective measures are very difficult to analyse.
Objectives	Clarity of (individual) objectives and needs is important for successful collaboration.
Barriers	Many of the barriers to collaboration are 'non-physical' (e.g. intuitive, psychological & expectations)
IPR (intellectual property rights)	Individual perspectives on IPR are an important factor in collaboration. A relaxed attitude and a model agreement helps contract negotiation (the university owns the IPR but there should be agreement for exploitation within industry).
Understanding & trust	There are barriers of understanding and negotiation, including language, objectives, motivations, and working practices. Mutual understanding helps develop trust.
Project management	The management approach adopted depends on the nature and scale of the project. The use of standardised project descriptions, e.g. ROAME, helps common understanding. Review groups are also important for the exchange of ideas. The management model should not be applied rigidly but flexibly.
Formality	If networks are made too formal or procedural, the benefits of informality are lost. A more formal approach is needed for large and multi-national networks (because of language differences).
Meetings	The role of the meeting chairperson is important in negotiating and moderating communication. They should ensure that there is equal contribution by all participants in the meeting.
Structure	Networks are composed of individuals, not organisations; therefore it is difficult to measure the success of a network. Substitutes may alter the dynamics of a network (because they are not aware of the histories and how the network participants work together).

The last topic clearly needs to be explored further in the interviews with the collaborative research facilitators so that different perspectives on this aspect can be compared. The interviewee also mentioned that collaboration between industry and academia is a 'learning process' where individuals learn from experience and mistakes. Another interesting issue that came up is that individuals with prior experience in R&D can help craft-based companies (e.g. water companies) work with universities that will provide them with the scientific knowledge needed to enhance their technology, processes or products.

The experience of the scoping interview indicated that without sufficient structure in the interview agenda, any information gained would be lengthy (in terms of pages of transcripts) with a significant amount of irrelevant content, making data analysis difficult. This confirmed the proposition stated in Chapter 3 that the most appropriate and efficient structure for the interview survey would be a semi-structured format which allows participants the freedom to reflect and talk around a subject whilst constraining the content to specific areas. The need for a better distinction in the survey questions between collaborative research networks and collaborative research projects was also identified as it was evident from the scoping interview that motivations and communication and management methods differ for these two types of collaboration.

4.2 Interview Survey – Description of activity

This section describes the survey carried out with individuals involved in funding and managing industry-academia collaborative research networks and projects in the UK. Sixteen interviews were conducted with individuals at four UK Research Councils (EPSRC, ESRC, PPARC & NERC), at the Office of Science & Technology (Department of Trade & Industry) and at industrial liaison departments or independent technology transfer organisations based at five UK universities (see Section 4.2.2 for details of how the participants were selected). The interviews were conducted between November 2002 and January 2003. The objectives of this activity were:

- To obtain information regarding the extent and nature of industry-academia research collaboration in the UK;
- To elicit respondent perceptions on the effectiveness of current or previous research collaborative projects and networks in terms of motivations, management, and communication;
- To identify best practice elements for effective industry-academia collaboration.

The exploration carried out in the scoping interview (Section 4.1) and the information gained from the research background (Chapters 2 & 3) supported the design of the interview questions (see Figure 4.1). The development of the interview template is explained in the next section. In the following section (Section 4.2.2) the technique used in selecting the respondents and the organisation of the interview survey are described.

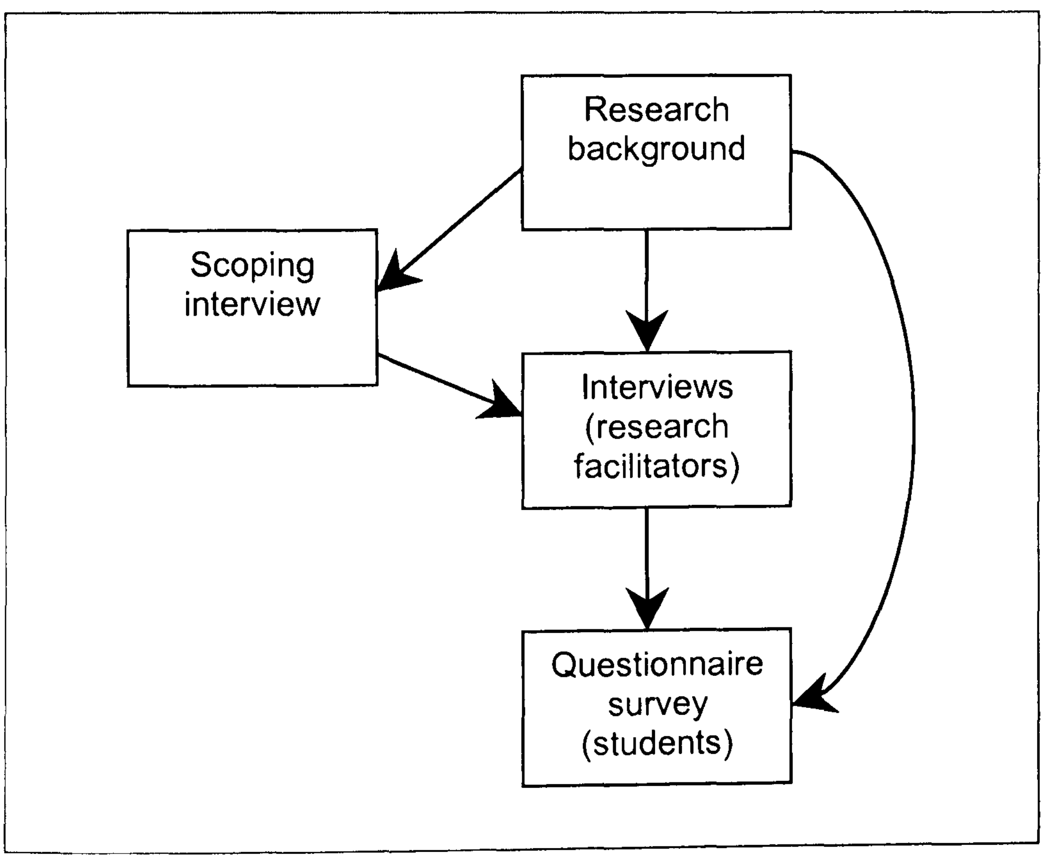

Figure 4.1: Relationship between research activities

4.2.1 Interview template

As the interviews were administered by an interviewer, a template was developed providing procedural instructions and a series of primary questions (or prompts) as starting points for sections of the interview (see Appendix 4A). The questions were devised in a semi-structured format. The topics that the questions covered are based on the research questions, on the issues that emerged from the scoping interview and on the objectives of the interview survey (outlined at the beginning of this section). The questions covered the following topics:

- Experience of industry-academia research collaboration (role in organising collaborative 'projects' & 'networks');
- Perceived motivations for industry-academia research collaboration;
- Nature of industry-academia collaborative schemes (type, lifecycle, etc.);
- Evaluation of industry-academia research collaboration (measures & techniques);
- Barriers to effective industry-academia research collaboration;
- Effectiveness of collaborative research schemes in terms of management and communication (models & modes);
- Best practice elements for effective industry-academia research collaboration.

As in the scoping interview, the first questions aim to elicit information on the interviewees' background, both professional and educational, including their current work role and their experience of (managing) industry-academia research collaboration. The next question asks the respondents about the motivations for industry-academia collaboration from both sides of the collaboration (i.e. industry & academia). Most of the subsequent questions, in general, are asking the respondents about the nature of the collaborative projects or networks that they fund or manage, including the type of management and communication structure they use, the measures or techniques that are used to evaluate the effectiveness of the collaborations and the barriers or problems that have occurred (or may occur) in the relationships. Two of the questions asked the interviewees to describe specific examples of 'bad' and 'good' collaboration, in order to tease out some of the factors contributing to each case (as well as to avoid too general an impression of industry-academia collaboration). Definitions of what a network is and what a collaborative project is are also provided at the start of the interview template for clarification.

The interview template was revised following the first day of interviews (three completed interviews) as respondents found questions that were designed (in the original template) to measure the impact of specific factors (barriers) on the effectiveness of industry-academia collaboration difficult to answer. This was due to the provided Likert Scales which did not allow for the fact that the nature of collaboration changes over time and some of the barriers or problems could be overcome with time. Following the template revision, interviewees were instead asked to comment on each of the listed potential barriers to collaboration, as well as any others they thought were significant. Another set of Likert scale questions that were intended to measure the importance of specific best practice issues was also removed as they were believed to be 'leading' questions. This question was therefore changed to ask the interviewees to suggest five aspects of effective collaboration which might be used to formulate best practice. Appendix 4A shows the revised interview template. The next section describes the organisation of the interview survey.

4.2.2 Logistics

In Section 3.4.2 of Chapter 3, it was explained why industry-academia collaborative research facilitators were selected as a response group for the interview survey. The process used in selecting the sample group is now described. The websites of all six UK research councils as well as those of a selected number (five) of universities were used to identify individuals shown to be responsible for managing or facilitating relationships between industry and academia. A database was created containing the names (both individual & organisation), work role and contact details of thirty individuals. All these individuals were contacted by phone and sixteen of them agreed to be interviewed; the respondents come from the following institutions:

- Engineering & Physical Sciences Research Council (EPSRC)
- Natural Environment Research Council (NERC)
- Particle Physics & Astronomy Research Council (PPARC)
- Economic & Social Research Council (ESRC)
- Office of Science & Technology (Department of Trade & Industry)
- Cambridge University
- Cranfield University
- Oxford University
- University College London (UCL)
- University of Manchester Institute of Science & Technology (UMIST)

An introductory email was then sent to all the interviewees providing them with background information on the project, explaining the objectives of the project and asking when they might be available for interview. A letter was also sent out a couple of weeks before the interviews to remind the interviewees of the session date and time and to give some indication of what was to be discussed and how the activity would be carried out (including statements on research ethics & proposed methods for analysing the data; see Appendix 4B).

The face-to-face interviews were administered by an interviewer and took place at the workplace of the participants. Most of the interviews took place in small rooms so that background noises could be avoided. The shortest interview lasted for about 40 minutes, while the longest progressed for an hour and 30 minutes. The variation is mainly due to the characteristics of individual respondents - some talked extensively and spent much time answering the questions, while others only had a limited amount of time for the interview or gave quick and/or concise answers. At the beginning of each interview, the participant was reminded why data was being collected and the purposes for which it was to be used. All the interviewees were asked for permission to record the interviews with a voice recorder. Permission was granted by all the participants, who were assured that anonymity would be preserved and that the data provided would be treated with confidentiality (these procedures conform to University and British Psychological Society guidelines on ethical research practice). The organisations that sponsored and conducted the survey (EPSRC & Cranfield University) were also made clear to the respondents.

All interviews were recorded on a digital recorder and the voice files were downloaded to a computer for transcription using 'Olympus DSS Player Pro' transcription software. The transcripts were then returned to participants for authorisation and any comments before commencing the analysis. All the transcripts were authorised and both electronic and hard copies were made, providing a permanent data set that is available for use with a variety of evaluation methods. Once data analysis was completed, a report summarising the findings of the interview survey was sent to all the participants. The analysis process employed in sorting, analysing and making sense of the data is described in the next section.

4.2.3 Data analysis

The first element of the data analysis process involved reading through each interview transcript carefully (2 or 3 times), identifying, highlighting and extracting the most relevant, meaningful, and interesting parts of the text. Each highlighted segment was coded to indicate the theme or category it relates to, using the following classification; Motivations & Benefits, Barriers & Problems, Nature & Effectiveness, Evaluation, Management, Communication and Best Practice. Code labels were attached to segments of text using comment 'balloons' (reviewing tool in Word) placed alongside the text. Each of the main themes was allocated a colour code (using different highlighter pens) enabling the relevant codes to be searched quickly in the texts. Re-reading the transcripts enabled a series of sub-categories to be identified for each theme. The codes are listed, with their definitions, in Appendix 4C. Additional codes were also created for other interesting parts of the text, for example, phrases or expressions, and issues not directly related to the main themes (e.g. sectoral variations, background information on the interviewees and their organisations, etc.). The coding process was a difficult and time consuming task, both in terms of the definition of the categories and with regard to distinguishing between categories and applying these to the data. Because the interviews were only semi-structured, respondents sometimes mentioned relevant topics at different times during the interview, not only immediately following the related questions.

From each interview transcript the relevant, and original, text segments (with their corresponding line numbers) were copied and pasted using a word processor into tables created for each of the seven major themes. All the individual thematic tables were then collated to form seven large thematic tables, with the ID codes for each interviewee placed in the column headings to enable comparisons to be made across individual cases. The text segments corresponding to a specific sub-category under each major theme were classified into rows within the thematic tables (with the sub-category labels as row-headings). The resulting tables were 'double-checked' by a colleague to ensure that the segments corresponded well with the categories that they were assigned to. Some quasi-statistics were also carried out on the data, which involved counting the number of times a subject (e.g. a particular problem factor) is mentioned as a rough estimate of its frequency. This was facilitated by further reducing the data in the thematic tables by deriving keywords for each row and classifying the responses using these keywords (into new tables). These results were also double-checked by a colleague to ensure accuracy. The interview tapes and transcripts and the thematic tables are available for inspection if required. The interview survey findings by each theme (and related sub-categories) are narrated in the next section.

4.3 Interview survey - Results

The next seven sub-sections present the results of the interview survey, each of which corresponds to one of the main themes explored with the interviewees as follows: i) 'Motivations' for and 'Benefits' of collaboration, ii) 'Barriers' and 'Problems' in collaboration, iii) 'Nature' and 'Effectiveness' of current schemes to support collaboration, iv) techniques for 'Evaluating' collaboration, v) 'Management' models, vi) modes of 'Communication', and vii) 'Best Practice' advice. The numbers at the end of the direct quotes provided in this section are the interviewee identification codes. Other evidence from the interviews is paraphrased in the text. The last sub-section (4.3.8) provides a brief summary of the findings.

4.3.1 Motivations for & benefits of collaboration

There are clearly mutual benefits to industry-academia research collaboration and many interviewees emphasised this, pointing out that the relationships would otherwise not work. To give one example of what they said, here is how one respondent from a university industrial liaison department described it:

> *'It's a two way process... Very crudely, I mean the bottom line for all this in my view is very much mutual benefit... So there's got to be a reciprocity in the relationship and if it doesn't work like that it's not going to happen.' (0024)*

Several interviewees expressed the view that it is hard to generalise on the motivations of different partners as there are many different types of universities and companies, and the motivations also vary individually. An interviewee at a research council stressed this by saying:

> *'... [the motive] varies tremendously from individual to individual, across disciplines, depending on the problem...' (0031)*

A wide range of reasons that industrialists and academics collaborate came up in the interviews and these are discussed in the next two sub-sections. As indicated by another interviewee from a research council, you will see that:

> *'It's not just the obvious things you can write down, i.e. intellectual property and all these benefits. It's all that informal knowledge, tacit knowledge... and all these other things help both sides...' (0028)*

The third sub-section below looks at the reasons that industrialists and academics get involved in networks. Because of the large variety of motivations that were mentioned during the interviews, no clear differences could be identified in what the respondents from the different types of organisations (i.e. research councils & university industrial liaison centres) said. But one aspect worth mentioning here is that several of the respondents from the research councils gave a similar response on what their own motivation for industry-academia collaboration is: to meet their mission statement to improve the UK's quality of life and economy. Finally, as revealed by several respondents, there are also unexpected benefits that emerge during collaboration, for example the two parties may in fact know more about each other than they thought or opportunities for further collaboration arise. One interviewee from a university claimed that

> *'There should always be some benefits that are unexpected' (0038).*

i) Industry

Acquiring or extending their knowledge and obtaining access to university facilities or resources, particularly students, were the most frequently mentioned reasons for industry to collaborate with academics. Collaborative schemes such as Co-operative Award in Science and Engineering (CASE) and Teaching Company Scheme (TCS) allow companies to have a student or post-doc without any long term commitment and the chances that they stay are very high according to one research council interviewee. Money is also evidently quite an important motivation, whether companies want to make money or want to avoid spending money on doing long term and riskier projects in-house (personnel costs, costs of setting up labs). Some respondents at the university industrial liaison centres pointed out that many companies come to them for immediate problem solving (answers to simple questions), not just long term research which one interviewee described universities as being *'perfect bases' (0024)* for. Another respondent stated that companies are keen to work with the big universities to improve their reputations, as the following statement shows:

> *'... so they can say look, we fund research. We are not just making a profit. We are putting money back in to developing more things in the future... Because they can get a few brownie points and tick a few boxes' (0035)*

Raising their profile in academia is also a mechanism for encouraging good staff to want to join their company, according to one interviewee. Identifying or realising downstream benefits is *'more tricky' (0023)*, as one respondent from a research council described it, because industry often does not get the profit that they are looking for or because their motivations and objectives change before the end of the project. Lastly, one university interviewee was certain that by any measure the degree of transfer of benefit into industry is approximately zero and believes that the idea that the government calls this "*science base*" is:

> *'... a very hypocritical phrase because it implies that if you took it away, industry will collapse. In fact if you took it away, industry will be a lot better off because it would have been paying less tax' (0039)*

ii) *Academic*

Nearly three quarters of the interviewees cited money, either for themselves or their research, as one reason that academics collaborate with industry. One university respondent interestingly stated that academics:

> *'... are pathetically grateful for quite small sums of money' (0039)*

Industry's leading edge problems which cannot be tackled in the private sector are *'the absolute bread and butter of academic research' (0024)* as another university respondent put it. According to this respondent, some academics find it much easier to get money out of industry as they do not like the politics of the research councils (peer review) and charities. This was also indicated by another interviewee who stated that academics like to free themselves from the burden of the continual application for grants by getting funding from other sources. Other motivations relevant to academics that were provided by the interviewees included developing their reputations, finding and working on new or real problems, and seeing their science being used. But, as pointed out by one university respondent, different academics, for example, *'cutting edge'* (0029) academics, junior academics or academics that are not as eminent are driven by different sets of drivers. In two interviews, the academics' motivations were split into those of university managers and those of research academics, which were suggested to be different. As indicated several times, some academics are committed to seeing the benefits of their research and want to have an impact on society, as it gives them a lot of satisfaction and also helps develop their kudos. University managers appear to be driven by the financial reward, which is regarded as an important income stream. Another suggested motivation for universities is their desire to ensure that they have an important role in society, which is vital for their future, as there is now a better awareness of the value that they contribute to society.

With regard to students, one interviewee from a research council mentioned that the engineering doctorate directors see the benefits of placing their students in companies. They are *'getting a much more rounded student' (0036)*, for example their students acquire better soft skills. There is evidently a reverse trend in connection with access to facilities (i.e. industry to academia) as some universities cannot afford state-of-the-art equipment. Another respondent from a research council expressed that there is probably insufficient recognition of the benefits of the reverse flow (e.g. equipment & training). Regarding downstream benefits, academics get several rewards out of collaboration including, good (& significant numbers of) publications, well trained students, and case studies and material that they can use for teaching purposes.

iii) Networks

According to many interviewees, the main reason industrialists and academics get involved in networks is to meet or interact with other people and this could be because, as one interviewee from a research council described it:

> *'Networks provide a way of people getting together in a formal or informal way and... it's on neutral territory, so it allows people to meet each other where they wouldn't normally.' (0023)*

Another research council respondent stated that networks are a really good opportunity for industrialists to find and meet key or expert academics in a field and to identify potential partners for future projects. As indicated on several occasions, sharing knowledge, information or experience is another important motivation for networks. Many companies want to avoid missing out by knowing what is going on and academics like to identify key challenges or problems in an area and also to discuss the research that they propose to do. There is now greater awareness that networking can be a good thing and in some cases you can achieve 'genuine synergy' (0024), as one university respondent put it. This interviewee also pointed out that the benefits of networks:

> *'... are often the soft, intangible outputs, which is the getting together, the networking, people meeting people, [etc.]...' (0024)*

Another university interviewee mentioned that people now realise that sharing information is *'more powerful because you could build upon that' (0038)* and that networks can help you do that. One respondent from a research council stated that networks are one way of stimulating and nurturing new research areas, particularly interdisciplinary activities.

4.3.2 Barriers & problems in collaboration

The participants in the interviews were asked questions related to four issues from the literature review (Chapter 2) which are seen as significant barriers to industry-academia collaboration; these are i) organisational cultures, ii) differences in desired timescales, iii) intellectual property rights (IPR) and iv) individuals' disciplinary backgrounds. Their responses on these issues are discussed in the next four sub-sections. A number of other obstacles that can occur in industry-academia collaboration were also brought up during the interviews and these are discussed in the last (fifth) sub-section.

i) Organisational Culture

Over a third of the interviewees believed that organisational culture is an important potential barrier in industry-academia collaboration. As pointed out by one interviewee from a university technology transfer centre, a classic and obvious conflict here is the right to publish or the value of publishing research results. Academics want to publish because it is their job (influence of the Research Assessment Exercise), but industry prefers not to publish as they want to have a commercial lead. This interviewee used the phrase "*different universes, different planets*" to describe the difference in industry and academic cultures and stated that:

> *'… metaphorically it's quite like that and it's not a criticism of either, it's just a fact of life, that the roles of the two organisations are fundamentally different.' (0030)*

But, as emphasised by other respondents, this is often a sectoral issue as all universities are different and all companies are different, and there are also individual differences within each sector. There have been several responses in the interviews describing academic culture as being a problem in various respects. For example, with regard to exploitation, personal reputation, timeframes, trustworthiness, bureaucracy, etc. There is evidently a range of different attitudes within academia, for example there are some academics who *'wouldn't commit to doing anything outside their own little box'* (0034) as one university based interviewee put it. Another university respondent interestingly described academics as being *'absolutely tribal'* (0026). Many academics in traditionally funded universities will not work with industry because it would destroy the university's reputation according to one interviewee (also from a university) who also believes that not all traditional academics will be able to adapt to the culture of universities which do a lot of work with industry. According to another university respondent, some *'cutting edge'* (0029) academics are very difficult to work with because they are very arrogant. This respondent stated that their institution has some academics who are becoming very entrepreneurial and aggressively commercial, and who would give most business men a run for their money in this respect.

There were similar views from respondents based at the research councils, for example one mentioned that there are still many academics who find it a challenge talking to anyone who has anything to do with them and that some academics, particularly eminent ones, tend not to see the value of collaboration. They do not think its worth getting involved unless they get credit (i.e. increase in personal status). Another respondent stated that these problems are to a certain extent backed up by the RAE (Research Assessment Exercise) as it does not explicitly reward collaboration. According to a different interviewee, industrialists sometimes see academics as poorly focused and untrustworthy in terms of confidentiality. So, as indicated by one respondent, the differences in organisational cultures might affect the priority given by different organisations to collaborative schemes. In some cases, the culture issue is evidently related to timescales, for example, the short or long term views of the different parties and the different working paces of industrialists and academics. In general, industrialists tend to want to do things very quickly and have much shorter time frames for results, particularly those from small companies who are more business product oriented. Academics on the other hand prefer doing long term research and do not like working to deadlines. Several respondents highlighted the problem of the small company (SME) culture and stated that it is very different to that of academics, and interestingly, on two occasions, that of large companies, who tend to think longer term. These differences might therefore lead to different expectations, which you will see later, is another important issue in industry-academia collaboration. One university respondent claimed that even if there are cultural conflicts, people can work around them if both parties are still willing to pursue collaboration. According to another interviewee the cultural problem can be overcome if there is understanding and trust between individuals, as it is they who make the cultures. There have been several indications in the interviews that provision of a facilitating interface such as a relationship manager, or even champions, can help defuse this cultural problem as the following statement from a university respondent shows:

> *'... to have a relationship manager interfacing between there and the university... can defuse that because the crudeness of the industrial culture never actually is in the face of the academics.' (0029)*

ii) ***Timescales***

Several respondents in the interview survey mentioned that differences in desired or anticipated timescales can be, or sometimes are, a problem because it depends on the nature of the work and also on the type of universities or companies involved. Some difficulties occur because companies have short term views due to their budgets, whilst the basic research which most academics do is naturally long term. As indicated in the previous section, it is part of organisational culture that academics tend to have longer term views and work more slowly than industrialists. One interviewee from a research council mentioned that:

> *'One of the biggest opportunities for misunderstanding is timing issues. Short term versus long term... That does offer lots of room for confusion and disappointment... ' (0031)*

A university respondent expressed that many of their academics will not engage themselves with near to market problems. They want to be engaged in basic research so timeframes are not important if a relationship is at that level because people are not chasing them. Another university interviewee mentioned that although universities generally do not exist to do very short term projects on a research basis, there are some universities that are setting up very effective contract research units where they can turn round companies' needs very quickly. A different university respondent claimed that this issue is a problem that arises before the work is done:

> *'That's a problem that causes industry not to ask a university to do stuff. So it's more difficult to get over because you then have to send people out to persuade them...' (0035)*

This interviewee however believes that there is now a change in industry's perception of universities as a whole and that nowadays academic institutes are generally considered to be much more business based, not inferior. There have been some statements from the interviewees that highlighted the problem of the length of the application process to get funding or to set up collaboration schemes, due to the bureaucracy associated with it. This is evidently a problem for industrialists as their time is limited and expensive. Another issue related to timescales that emerged from the interviews is the limitation of people's availability, particularly where collaborative projects are treated as '*add-ons*' to their standard job function. This creates many problems including not giving enough attention or commitment to the project and cancelling meetings thus slowing down the process. This is the case for academics that spend all or much of their time teaching.

iii) Intellectual Property Rights (IPR)

Nearly a third of the interviewees stated that IPR is an important and problematic issue in industry-academia collaboration. Many respondents however pointed out that it can be mitigated by addressing the issues with everyone involved in the collaboration at the beginning of the relationship (e.g. set up IPR agreements). This is illustrated in the two statements below, the first one from a university respondent and the latter from a research council interviewee:

> *'Do IPR early… Get it out the way, done with and it doesn't become a stumbling block.' (0038)*

> *'… if you build that one in the beginning and you trust each other, then it's not really a problem, but if you don't attend to it, then it's a killer.' (0023)*

IPR is often a stumbling block because many companies feel that if they invest money then they should own the IP exclusively, although the general rule is that the university owns it. There is also a conflict between IP protection and academic publication. Many academics want the freedom to be able to determine what happens to their IP. One respondent from a university mentioned that they try to separate the idea of 'ownership' from 'the right to exploit' in predetermined areas and have not found much opposition to the approach although they also pointed out that they do not always succeed. One research council interviewee stated that IP is always associated with money and universities are greedy and more conscious of it than they used to be. This was also indicated by another research council interviewee who noticed that recently universities are *'taking a harder line on IPR'* (0036) and this is creating problems with some companies. Again the significance of this issue is variable across sectors. For example, patents are important for pharmaceutical industries and copyrights are essential for computer industries. According to one university respondent, copyright (particularly for digital materials) is causing most of the biggest difficulties, whereas patents are relatively straightforward to manage. There have been some indications that IPR was a big issue in the past and that this matter is now improving as both sides understand each other better and there are routine solutions to how you handle IPR. One university respondent mentioned that IPR frightens people who do not know anything about it and that although the solutions are not widely known, this problem can be relatively easily solved by educating people.

iv) Disciplinary backgrounds

The effect of individuals' disciplinary backgrounds on collaboration varies by industrial sector or field of research. It can be very important in some sectors and less so in others, depending on the nature of the work that the collaborating organisations do, the type of people that work within these organisations and also how much collaboration experience the organisation or individual has. The pharmaceutical industry, for example, is used to doing long term 'blue skies' research and has a long record of good links with universities. Also, as claimed by a university respondent, their people are indistinguishable from academics except they are paid more and have better equipment, so the two partners have much in common and work together naturally. Another university respondent also believes that scientists in companies are quite like scientists in universities and that this probably helps build quite strong links. But, as pointed out by the previous respondent, there are some sectors such as manufacturing which do not have many graduates and who consequently may be more reluctant to work with academics. A different university interviewee mentioned that some of their academics perceived their background a barrier to small companies because they believed that they would be regarded as snooty and arrogant. One research council respondent gave the following statement about academics in engineering and collaboration:

> *'I don't think I've met an academic in engineering who hadn't had any collaboration, and who doesn't have an ambition to collaborate' (0036)*

This interviewee also pointed out that the extent to which industry is willing to collaborate may vary by discipline. For example, you are more likely to get collaboration in mechanical engineering than in civil engineering. Another respondent stated that there are different practices within different disciplines, for example a historian would work quite differently to a psychologist, but subsequently pointed out that this is probably too much of a generalisation. This is because this is a '*people issue*' as one university respondent put it, who stated that:

> *'Not all accountants are the same and not all chemists are the same.' (0038)*

This interviewee also highlighted the difference between academics who are applied researchers and have industry experience, and those who are pure researchers and generally do not have business experience, and are therefore more likely to find it more difficult to work with industrialists. This issue also depends on who is working together, as academics may get on better with scientists working in business as opposed to other business people. According to another university respondent, there are a good number of people in large companies who have no commercial idea perhaps because of their technical background. A different university respondent gave the following interesting statement on the disciplinary perspectives of their academics:

> *'... very few of them operate from a helicopter, most of them are stuck in their silo and they see the world from their disciplinary perspective. They don't necessarily see the world from a trans-, or a multi-disciplinary perspective... they see it from the tribal perspective of their disciplines.' (0026)*

Some interviewees indicated language as a potential problem related to people's backgrounds (e.g. the use of acronyms or jargon). They stated that it takes time to develop a common vocabulary that all parties can understand. Finally, some research council respondents highlighted the importance of interdisciplinary research, emphasising that they are trying to get people to think beyond their disciplinary perspectives, as the following statement shows:

> *'... the fact that people come from different backgrounds tends to be a positive aspect rather than a negative aspect.' (0036)*

v) Other issues

A number of other obstacles that can occur in industry-academia collaboration were mentioned during the interviews with the most frequently mentioned being related to the role of communication (e.g. people do not talk enough) and problems that occur in negotiations or agreements between parties, which are often slow and difficult to set up. Companies requiring exclusivity (confidentiality) often cause difficulties when negotiating contracts. One university respondent stressed that the exclusivity that industry wants is not always possible within a university setting because:

> *'... you are dealing with a specific research group and often they want the whole university to sign to say that they won't work with any competitors, which when you are dealing with a huge knowledge base... it's just not feasible.' (0035)*

One research council respondent claimed that where imbalances occur, they are largely down to where scientists are being told to interact against their wishes and they are not being allowed to negotiate sufficient flexibility for themselves. An additional factor that causes difficulties when setting up collaboration agreements is bringing together people that are collaborating for the first time. Another respondent mentioned that SMEs often do not know what to do with a collaboration agreement and that some medium size companies give it to their lawyers, slowing down the process. One university interviewee claimed that people attend courses about collaboration because they find negotiating a contract or license deal difficult and many people, even businessmen, have never actually made a business deal before. According to this respondent, problems occur where the two sides have different ideas as to what the contract is about:

> *'... the company, because they don't really understand the development process, think they're getting a developed product. And the university, who don't understand the industrial process, thinks if they show it works, they've done their job.' (0039)*

As pointed out by another interviewee, sometimes industrialists find it difficult to understand what research is actually about and particularly the fact that you would not be doing it if you knew the answers. These issues may lead to different expectations of the participants, which is another matter that came up several times in the interviews and which is, as stated earlier, related to different organisational cultures and timescales. One respondent claimed that the people who have different expectations are those who work in SMEs and believes that this is because there is sometimes a degree of overselling to them:

> *'... there may have been cases where that's been oversold to the SME and they've tended to think "well we're going to have a product here at the end of this", and actually they're not.' (0032)*

According to another respondent, there is some tension between what academics want to do and what SMEs want. Generally an SME wants a solution to a particular problem, whereas an academic may prefer a more generic type of solution that they can publish more widely. Another factor that frustrates academics and creates a lot of tension is company changes that occur during the collaboration process. For example, companies are taken over, liquidated, or change their strategic priorities. An additional issue mentioned a few times is personality related clashes. Collaboration may be more difficult or not work at all if the people involved do not like or get on with each other. On several occasions, the risks of collaboration were stated to be a problem, particularly for industry, which makes it difficult to secure funds or to make people interested in the challenge. One university respondent expressed that companies are quite often reluctant to collaborate because they feel that there is too high a risk of putting a lot of time and effort in trying to set up collaborations which do not actually come to fruition. One research council interviewee claimed that SMEs will always be wary of putting large sums of money into a particular project because of the risk and that there needs to be a balance between the risks and rewards of collaboration. This issue is not perceived as a problem for academics because they are used to conducting risky projects.

Some of the interviewees from the research councils indicated difficulties in the identification of suitable partners for collaboration. As pointed out by one respondent, getting the two parties together in the first place is a potential problem because the academics might not know the right people in companies, or even the right companies, and equally the industrialists may not know the right people in academia. One university respondent also believes that a lot of companies find it quite hard to find the right person to talk to within a university. Again the RAE (Research Assessment Exercise) was revealed to be a controversial issue by several respondents, mainly those from the research councils, as it does not consider industrial collaboration as high value and therefore can discourage academics from collaborating. It also causes problems with regard to publication as it encourages academics to publish a lot of papers which industry does not like. Here is what one interviewee said about the RAE:

> *'The RAE has been quite contentious for a few years now in terms of what we try and encourage people to do on the user engagement side... urging people to publish in academic journals and not to worry about Business Today... that's been the tension.' (0031)*

Finally, there were several indications in the interviews that if both parties, academics and industrialists, are determined to develop the relationship, many of the problems highlighted above can be overcome, and here is an interesting statement from a university respondent:

> *'I think the phrase "hurdles" not barriers is probably very apt, because it can throw things up every step of the way from contract negotiations and originally getting the collaboration right through to deliverables and objectives, but they are not insurmountable.' (0035)*

4.3.3 Nature & effectiveness of current schemes

i) General

In this section, the interviewees' views on current industry-academia collaborative schemes, in particular those set up by the research councils and government, are reviewed. The interviewees were also asked questions related to the timescales of these schemes and the effectiveness of collaborative research networks. The following text is classified into three subsections: a) collaborative schemes (& funding), b) timescales, and c) networks.

a) Collaborative schemes

As emphasised by one university respondent, there are so many initiatives for industry-academia collaboration and they can be contrived to some extent, but when they work well and things happen they can be very effective. This respondent also expressed that much time, effort and money are wasted on collaborative schemes but believes that they are improving because people are much more realistic about what the outcomes are and the management of expectations is much better now. There have however been a few indications in the interviews that complex schemes such as the government's LINK scheme discourage people from collaborating. One research council interviewee claimed that complex schemes are *'a collaboration killer'* (0023) because it takes a long time to set up the collaboration (> 6 months for application, approval, auditing, etc.). Another interviewee mentioned that the LINK scheme is quite complicated because the administration and financial arrangements are the responsibility of more than one government office. An additional perceived weakness of LINK is that it is only open to receive proposals over a limited period of time, as the following statement shows:

> *'... everybody knows it as a collaborative scheme with industry and they think that is the only opportunity to collaborate and then they go in and find that that particular program is not open to proposals at a particular time.' (0036)*

The LINK scheme also has a disadvantage from the point of view of SMEs because of the fifty percent contribution requirement. There is however one significant advantage of the scheme: as one respondent pointed out, LINK projects rarely die because they have an ability to bring in replacement companies if the project was showing potential. A major review has recently been conducted of the scheme and there are reports that a more flexible scheme will be introduced in the near future. One university respondent expressed that many industrial research contracts are increasingly complicated whereas those from the research councils are quite straightforward because every research council contract is the same and there is almost no negotiation involved. This respondent also indicated that several American universities provide specimen contracts that apply to sponsored research from industry on their websites and that such an approach should be adopted in the UK. Another university interviewee claimed that the research council activities might not necessarily result in success because their academics are not used to being supported; they are used to being *'solitary scholars' (0026)* and do not expect to, or even do not know how to be, supported by external organisations. There was one indication that some of the government schemes are more of an effort for social scientists as they do not fit neatly with how they operate. Also the potential support organisations within this sector are not as wealthy as those in other sectors such as engineering and medicine. According to one research council respondent, relationships between social scientists and non-academics are at a much earlier stage in their evolution.

There have been revelations by other research council interviewees that some collaborative schemes may have been oversold, particularly to SMEs, resulting in unrealistic expectations:

> *'... the danger there, or the big issue I think, over the last two or three years, is that some schemes have been oversold.' (0028)*

One research council respondent mentioned that PPARC are really good at making sensible funding schemes that have a short time scale and turnaround (8-9 weeks) and noted that the funding bodies have to be very responsive to the fact that it is hard enough to get good collaboration, let alone get suitable funding. So the role of public sector funds when needed is for it to be appropriate, easily accessible and for the application process to be easily understandable.

b) Timescales

According to one university interviewee, collaborative schemes are set up over defined timescales partly because of European anti-competition laws and partly due to considerations of expediency. They are nearly always set up on a tapering funding basis with the aim that they eventually become self-sustaining. The EU state aid rule was mentioned on two occasions as being an issue when arranging timescales. One research council interviewee claimed that it is considerations of unfair competition which is one of the major constraints on changing collaborative research. This interviewee also stated that they would ideally like to see a more flexible arrangement where they can get away from restrictive timescales, from some of the bureaucracy and just respond to the needs of the user community, but believes that three years is probably a rational period of support for networks and schemes like LINK. Another research council respondent mentioned that they would very rarely continue funding networks past three years because the network may not be doing anything that is of value to the members sufficient for it to survive afterwards. So they are sort of '*seed core funding*' (0036), i.e. nurturing them in the first instance, after which they should become self-sustaining. Some research council respondents have claimed that they try to be flexible with regard to timescales but as pointed out by one interviewee, it is unlikely to be real research if the timescale is short (< 3 years), so they would make a judgment depending on what the problem is and also on the budget requested.

c) Networks

Several interviewees suggested that there are too many research network activities in the UK and there is a risk that they may not be successful because people might find it difficult to decide which events to attend or may not have time to go to all of them. Some interviewees stated that the reason that people attend or do not attend network events often depends on other commitments they may have (*'opportunity cost'* - 0038). One research council interviewee believes that for every new networking group that is set up, another one should be closed down. This respondent also mentioned that people do not want to go to network meetings because they feel that they have more important things to do and believes that they will go if it is a significant part of their job, not just an 'add on'. A university respondent claimed that there is no clear policy by industry for which networks they will and will not attend, but believes that *'right event, right time, right place attracts people' (0038)*. A research council interviewee expressed that there are not too many networks because the portfolio is very broad, but agreed that industry find it difficult to decide which ones to go for because their time is limited and, whatever networks they are engaged in, usually involves them spending time and money. A different respondent believed that all networks are just transitory. Several university interviewees mentioned that the EC funded networks (thematic/framework programs) are beneficial and successful, and one respondent believes that this is because industrialists and academics are much savvier about what the possibilities are. Another respondent stated that there is certainly some commonly understood good practice emerging about the importance of these EC networks, partly because there is multi-partner collaboration there. The statement below shows the conditions under which networks can go beyond their funded lifetime in terms of core funding, given by a university respondent:

> *'... when you start to see genuine deliverables from them, where more than just the talking shops, when people actually start to do real work and you start to see things happen which wouldn't have happened otherwise and where there is genuine synergy.'* (0024)

Looking at the development of networks, another university interviewee believes that if people buy in and take ownership, they drive them forward and it has a different buzz about it as they feel passionate about what they are doing. A different university respondent emphasised that it would be beneficial if broader activities (e.g. research workshops on a nationwide scale) could be arranged that bring people from quite different backgrounds with different expectations and requirements into a situation where they can learn and understand a bit more about each other, on a regular basis.

ii) ***Success factors & factors which 'kill off' collaboration***

The next two sub-sections provide general overviews of the interviewee responses concerning important factors for successful collaboration and what factors can 'kill off' collaboration. The respondents were also asked to provide an example of 'bad' collaboration and an example of 'good' collaboration, in order to tease out some of the factors contributing to each type of case. A discussion of these factors has been placed in the appropriate sections (i.e.

good factors in the 'success' section and bad factors in the 'kill' section). It must be noted here that some of the interviewees have not, or have rarely, been involved at the coal face of collaborative projects or networks. Some respondents mentioned that they are just involved at the early stages of a relationship and then they back off, so they do not get involved at a deeper level. As a result of this, it was hard for some interviewees to provide examples of good or bad collaboration and some responses were based on specific cases that respondents had heard about or on work that was carried out by other organisations.

a) Success factors

Interviewees' responses concerning what they considered helps maintain successful collaboration were varied. However valuable or concrete outcomes and enthusiasm (energy) from collaboration participants were the two most often mentioned factors. A range of factors were also stated in the responses on good examples of collaboration but three issues surfaced frequently, these were: good management (e.g. clear agreements & regular meetings), good communication (e.g. regular & ongoing communication) and mutual interests or needs. Some of the good examples of collaboration resulted from valuable outcomes or outputs; a finding which agrees with what many interviewees said is an important success factor. Two examples of responses related to enthusiasm are shown below:

> *'... the thing that keeps them going is the enthusiasm of individuals on the whole... and the willingness of individuals to be fairly assertive in their own organisations when it comes to what they want to do.' (0027)*

> *'It will work if enough energy is put in from both sides in order to get the, sort of, sociology right...' (0030)*

The university respondent who gave the latter of these two examples also claimed that a management group can provide the '*social glue*' to ensure that the relationship works. Several of the stated success factors are evidently related to personalities. For example, a match of personalities (& skills), good working relationships and mutual trust or respect between participants is seen as beneficial, as the two following statements show:

> *'... they usually work best when the people on both sides have got mutual respect for each other and the people aspect of it work together.' (0030)*

> *'... if you like people, you tend to get on with them, and if you get on with people, you tend to trust them. And once you trust people then relationships tend to go...' (0038)*

Another university interviewee believes that if you put a relationship manager in at both ends (i.e. in both collaborating organisations), whose task is to meet regularly, to explore how the relationship is going, to look for ways of broadening it and deepening it, then you have a relationship that can survive. One respondent claimed that if you put industry in charge of a collaborative research project they will drive it forward because they are putting a lot of money into it and thus have a significant interest in it:

> *'... our experience is that industry are better at keeping driving it forward, getting past that first flush of excitement and keeping it going.' (0032)*

With regard to networks, one respondent from a research council stated that a network will survive if it can tap into additional resources and find some way of getting concrete outcomes that people can see as of value and ongoing. A university respondent also indicated that producing real results or outputs (e.g. paper, prototype, etc.), perhaps on more regular and shorter timescales, would help maintain interest. According to one research council interviewee, if a company provides a lot of in-kind contribution (support & personnel), you get a real true collaboration rather than just a successful front. Finally, two of the good examples of collaboration resulted from serendipity, for example the right people happened to meet at the right time and the right type of project was mentioned at the right time.

b) Factors which 'kill off' collaboration

Again, a variety of factors that can kill off collaboration were suggested by the interviewees, but personality clashes and change of personnel were the most frequently mentioned influences. Problems related to poor communication (e.g. lack of clarity or not keeping people informed) and poor management (e.g. poor or no agreements/structure from the outset) were also dominant themes in the responses. Amongst the provided examples of bad collaboration, the most regularly cited factors were company money problems (e.g. liquidation or cutting budgets) and a lack of contribution or attention from collaboration participants. One university respondent believes that personality is the biggest factor causing collaborations to fail, particularly if the lead people involved in the relationship do not get on. They can also fail where other people have set up the collaboration and they get researchers to work on it who then meet and dislike each other. An example of what may happen as a result of personality clashes in networks is shown in the following statement given by a research council interviewee:

> *'Very often these things become centred round a few people and so it's their club really rather than being a network.' (0023)*

Personnel changes were seen to typically involve industrial people who are promoted and move on. As pointed out by one university interviewee, the people who set up relationships tend to be terribly enthusiastic and almost inevitably because of that they are the ones who are promoted. One university respondent claimed that it can be a problem where the relationships are characterised as being one to one relationships between a manager in industry and an academic, which are *'terribly fragile'* (0029) because if the academic moves or the industrial manager is promoted, the link breaks down and they do not have any natural reasons to talk to each other any more. Another university interviewee believes that one of the most common reasons for failure is when the internal champions on each side change (leave) or lose interest, and stated that:

> *'... if you haven't got the internal champions on both sides throughout the whole of the relationships, it probably won't work. And that can happen as much on the business side as it can on the university side.' (0030)*

As pointed out by one research council interviewee, new collaborations are more vulnerable because there are the additional factors that the participants do not know each other, they might not get on and the company might not be used to supporting academic collaboration. New collaborations are more likely to collapse if the champions move on because they are much less stable, particularly if the participants have not developed much mutual respect during the first few months. It is very rare for something to go wrong on the academic side because:

> *'... they know what they are doing, this is research and they're used to it. The problems are more likely to come from the industrial side... because they've changed direction. This isn't something that they are interested in anymore.' (0032)*

This interviewee also mentioned that the rate at which companies change is '*alarming*' and that it is more likely to be a problem if a key individual moves. This factor was also indicated by a university interviewee who stated that if you lose the key people, it really kills the relationship. Company related factors were quite common in the bad examples of collaboration reported by respondents, in particular factors related to money problems. One cited example involved a company which cut its R&D budget by ninety-five percent because they were in serious commercial trouble and the collaborative relationship died as there was no money to fund the work. As pointed out by a university respondent, no matter how much you want to do it, the relationship will fail if there is no money flow:

> *'... we can't sustain the interest of our academics in this process, unless there is the likelihood of a continuing flow of money to fund research projects.' (0029)*

Another university interviewee believes that because of inexperience, people think big companies are stable like universities, whereas they are not and therefore it is the usual accidents of business, combined with amateurs on both sides that causes problems. An additional factor that can kill off collaboration is where there is not enough contribution from either partner to the work. Sometimes companies do not really understand what collaboration is really about and they just commission academics to do some work, whereas collaboration actually means working together and therefore equal contribution is required from both parties. This is indicated in the following statement from a research council interviewee:

> *'... if less than a quarter of it is being done by either partner, it doesn't happen because that's not collaboration.' (0032)*

Several examples of bad collaboration were characterised by unrealistic expectations from the academic side. One university respondent mentioned that some academics have a fairly short term and unrealistic view of why they are doing collaboration or what they are going to get out of it. Some academics expect a lot of money before they do the work or expect fairly major outcomes very quickly from the company which does not happen. One example described a situation where an academic did not deliver a piece of work because they were disappointed about the level of finance provided. There were also examples cited where industrial partners did not achieve what they expected from the collaboration. With regard to communication issues, one university respondent claimed that academics often fail to keep industrialists in the picture as to what is going on. It was also pointed out that people tend not to like sharing bad news. The issues related to lack of commitment or attention to the collaboration are mainly the result of people being under pressure from elsewhere in their work. Finally, one research council respondent interestingly believed that higher level politics is a factor that kills off collaboration because of the successions of new initiatives and new priorities, as the following statement shows:

> *'... if what you're doing falls down the list of priorities, then less resources are put into it and it just sort of fizzles away.' (0027)*

4.3.4 Evaluation of collaboration

The interviewees' responses on how they evaluate the effectiveness of collaborative projects or networks are described in this section. There were some similarities in the responses from individuals based at the research funding organisations on how they evaluate collaborative projects. Evaluation is generally done at the end of the projects by asking people who were involved for their views on how the project went and whether the original objectives were met, which are then marked by a peer review panel. All respondents highlighted the unreliability of this method because the evaluation is done just after the project finishes and therefore factors such as exploitation or long term impact are not picked up. Although such long term impacts are very important, they are very difficult to measure, as emphasised by several interviewees, because the criteria used are often subjective. The following statement shows how one respondent described it:

> *'This issue of how we look at the longer-term outcomes and benefits of projects is one that we are wrestling with in general I think.' (0036)*

Evaluation of longer term impacts can nevertheless be done. For example, by carrying out interviews with people who were involved in the project a few years after it finished. A potential difficulty with this approach, as pointed out by one research council respondent, is that when you stop giving grants people tend to stop talking to you. Another research council interviewee mentioned that they do not have any quantitative measures of the socio-economic impact of projects at the moment and so it is down to judgement, based on information (on project outputs & outcomes) collected as a whole. One respondent emphasised that it is easy to focus on the hard metrics, for example, number of people involved in meetings, number of patents, etc. because they are easier to measure than the softer ones. So there is a risk that the softer metrics will be ignored as indicated in the following statement:

> *'... unless we get a balance between those softer issues and the harder issues, we run a big risk of tilting the whole process towards the harder issues... in the longer run it's the softer ones that are equally as important.' (0028)*

Two of the interviewees from the research councils mentioned that they tend to use standard measures to collect general statistics and also to evaluate specific projects. With regard to the evaluation of networks, a list of recommended criteria for assessing the success of networks was provided by one interviewee.

These comprised simple metrics including the number of meetings held, the number of participants and the number of research proposals submitted. This interviewee also stated that their organisation was trying to find ways of identifying the number of new interactions generated by a network. Although this initiative was in its early stages, they gave the following statement:

> *'I suppose the ultimate test as far as our funding is concerned is whether it becomes self sustaining after the three years really.' (0036)*

A different respondent interestingly used a well-known phrase when discussing how collaboration should be evaluated:

> *'I think that you have to have two sets of performance measures. One of them is how effectively you lead horses to water and the second one is how often they drink.' (0023)*

Metrics suggested by this interviewee for leading horses to the water included how many conferences are organised, how many people come to them, how many people make enquiries about events, etc. and on the other side how many formal collaborations are instigated. They also reported that their institution actually measures the success of a network according to the 'buzz' that they are creating, as well as the level of repeat, i.e. does the number of people that regularly participate in the network increase? As pointed out by another interviewee, the evaluation method used depends on what your definition of success is:

> *'... first of all define for me what success is, and then we'll have a go at measuring it, and that's why it's all such a very very difficult area.' (0032)*

Evaluation is complicated by the fact that different organisations have different definitions of success, for example, some are merely interested in the outputs of collaboration (e.g. numbers of papers, etc.) whereas others want to know what the (long term) outcomes were. The interviewee who provided the quote above believes that one measure of success is whether the two sides carry on working together afterwards. The research council interviewees are clearly concerned about how evaluation is done, and are continually trying to find novel and better ways of evaluating collaborative projects and networks. Also with knowledge transfer being such a hot topic at the moment, the research councils are currently looking at how knowledge transfer can be measured and what can be done to improve such flows.

Like the research council interviewees, several university respondents mentioned that evaluation of industry-academia collaborative projects or networks is very difficult. There were a few similarities in the type of metrics that the university based interviewees mentioned, including the number of contacts established and whether there were subsequent or continual links or activities. One respondent believes that a good successful collaboration generally leads to further opportunities and therefore stated that you need to look at what the 'follow on' is and what the relationship is after a project is completed. This respondent gave a similar response to that provided by one of the research council respondents on how networks can be evaluated:

> *'... it's how many people turn up, do they continue to turn up, do they bring new people, do they then influence the operation of the new network and also, then the other side of the coin, is did they meet people, were collaborations developed as part of the network in terms of projects, products, you know, clubs, whatever.' (0038)*

Some of the university interviewees mentioned that they are still at an early stage of developing their evaluation strategies but one respondent stated that the metrics will certainly be about *'customer satisfaction'* (0034) in some form or other, and cited *'repeat business'* as one way of measuring it. A different interviewee interestingly asserted that, because the issues are very soft and subjective in many areas, you have to measure them to some extent by:

> *'... if people say, it looks like a camel, it's a camel. If people say, it's a success you know, you've got to believe them.' (0024)*

This interviewee also stated that there is quite a raft of variables you can look at, but how you prioritise them, put them all together and package them, is very hard and described this as *'one of the biggest conundrums of academic-industry links'*.

One respondent had a very simple view of evaluation and stated that they believe in counting pounds because a measure is unlikely to be substantial if you cannot add it up. Another interviewee mentioned the concept of a score board which measures the aggregate deliverable to the university to evaluate the benefits that technology transfer brings to their institution. No mention was, however, made by this respondent of the benefits to other parties. This was also the case in another interview with a participant based at an independent technology transfer centre who generally evaluates project success by counting patent applications. This interviewee pointed out that although there are many things that come out of the technology transfer process that can be counted, it is the quality of the decision making that goes into each stage that is critical, not the output. According to another respondent, patent counting is not a good measure of technological productivity. Interestingly, only one interviewee at the universities discussed the measurement of socio-economic impact. This interviewee expressed the view that measuring such impact is very difficult and gave the following statement:

> *'It's much more clearly a set of social processes that would elucidate rather than a metrical approach that will elucidate whether or not you are getting anywhere.' (0026)*

This respondent also mentioned that they commissioned a report from SPRU which looks at 'third stream metrics', i.e. not just of the commercial benefits but also of the many other ways in which university adds value to society (economic & social benefits). One of the conclusions from the report was that metrics in this area are very, very difficult. This interviewee also claimed that they are very aware that they need to be *'cleverer'* about metrics because they are not nearly good enough at collecting them.

4.3.5 Management of collaboration

This section describes the interviewees' responses on management related questions, for example what type of project management strategy or model they use, or would use, for industry-academia collaborative research schemes. Several interviewees, in particular those from the research funding organisations, emphasised that the type of management model or structure used depends on the size of the collaboration and also on the type of sector that is involved, so a single specific model would not be appropriate in every case:

> *'... one size doesn't fit all for policy and for managing of interactions... if you want to manage and facilitate that process [knowledge flow] you need to take a different approach to the different sectors.' (0028)*

As emphasised by one interviewee, all collaborations cannot be treated the same. Several respondents believe that large collaborations need a more rigid structure and that management of smaller collaborations should not be too prescriptive, depending on what is required and on the timescales involved. One respondent maintained that it is much easier to have strict project management for larger collaborations. This is also the case for collaborations which have participants from outside the UK because if there are language barriers as well, then to have meetings with a proper agenda is quite fundamental to getting the collaboration to work. According to another respondent the EC funded framework programs are quite prescriptive partly because there is multi-partner collaboration. One interviewee mentioned that the best large collaborations tend to have spokesmen who act as the external face of the consortium. Where the collaboration is between two people, you still need to have regulated project management except it does not need to be such a formal model. One interviewee believes that there should be a 'modicum' of management and another respondent indicated that there should be a balance between letting the collaboration have freedom to build up and giving them some structure. According to a different respondent the structure is much more robust if the relationship is developed between two institutions rather than between two individuals. This interviewee stated that they now have more robust structures for their collaborative schemes than they did, particularly for spin outs. One of the research council interviewees stated that for their research projects, they ask for a GANTT chart to indicate how the research will progress, what key actions will take place and when they are expected to take place.

All the respondents based at the research funding organisations pointed out that it is valuable to have a management or steering group. There is generally one on the collaborative projects they organise, with some groups having both academic and non-academic representatives. According to one interviewee, a two level management structure is usually always necessary which entails an over seeing or steering group and a project management group with an identified project manager. Having a management or steering group ensures that regular meetings take place, usually with an agenda. All the university based respondents also mentioned that it is useful to have a management or steering group, and also in some cases a project manager. One respondent claimed that it is now common place that these collaborations will have some sort of steering, management or technical advisory committee or group. According to this respondent, these groups help ensure that the relationship works by meeting up regularly.

Setting up collaboration agreements at the outset are evidently very important for making decisions, sorting out issues such as intellectual property rights (IPR) and confidentiality, and also deciding how to deal with potential changes in a project's direction. One respondent stressed that they would not allow any project to start, or at least would not distribute any funds, until a collaboration agreement has been signed by all the participants involved. This ensures that everybody goes in with their *'eyes open'*. Having an agreement in place makes sure that participants all think about, discuss and understand certain issues before the project starts; for example, what IPR are they bringing into the project and what is going to happen afterwards:

> *'... we try and set out as much in the collaboration agreement as possible, because the experience suggests that if you don't sort it out at the beginning, you are going to have horrendous troubles later on.' (0032)*

Many of the university respondents specified that research contracts or collaboration agreements are important and that they should be signed at the beginning of a collaborative project. This is shown in the following statement:

> *'... I really learned from experience that unless you've got a good, clear, well crafted agreement in place on day one, and something goes wrong, you really are in a mess... get into people's heads that you have to have that, you have a future proof relationship against change of personnel and change of whatever...' (0024)*

One respondent claimed that there always has to be a research contract that defines the deliverables and the money flow, and also puts down an audit trail so that everyone can see that the money is being spent appropriately. A different respondent stated that the agreements should be sorted out quickly so that the collaboration can go ahead with a minimum of fuss and bother, and pointed out that the importance of trouble spots such as IPR is tiny compared with the importance of the purpose of the relationship.

With regard to who should deal with contractual negotiations, one university interviewee stated that these should be conducted outside the academic, technical, managerial sphere and should be handled by the central functions of the university. Another interviewee also indicated that it is best if technology transfer/industrial liaison office deals with contract negotiations because they have a better overview of what is going on and they have a working knowledge of the registrar, the official side of the university and what their requirements are, whereas an academic is much more focused on their research. A different respondent pointed out that collaborators should avoid complicated agreements and should try to have some flexibility to tailor the agreement to suit particular companies. This respondent also gave the following statement:

> *'I think trying to get the nuts and bolts, you know, dotting the i's and crossing the t's of the management process as in writing any contract, you want to try and get that as slick as possible.' (0034).*

According to one interviewee, you hardly need a contract in *'genuine collaborations'* (0039) where there is no money changing hands and where there is a will to have an agreement. Another interviewee stated that over a period of years they have had a considerable proliferation of forms of contracts for different kinds of arrangement. On the other hand, a respondent from a different university cited that they have standard agreements for very low level relationships right the way through to the commercialisation of research via, for example, spin off companies. They have standard non-disclosure agreements in place for meetings with industry, either at their own instigation or the company's instigation, and also standard agreements for IPR protection. They take steps to make sure that the company understands where their rights are but also where they may want to recognise the contribution of the students. The students are also involved in the agreements and they sign and keep a copy just as the company and university do. One interviewee pointed out that it is important to break down the words R&D (research & development) into its different types of activity and to define what the activities are, because different types of R&D service need handling differently.

Amongst the interviewees' responses, we can identify four issues highlighted as particularly important by the respondents in the management of collaborative projects or networks; these are: i) intellectual property rights (IPR), ii) participant expectations, iii) results exploitation, and iv) modifications in a project's direction. With regard to IPR, some of the research council interviewees mentioned that it is an issue that can be managed by the academics. One interviewee expressed that their rules are very clear that collaborators are not allowed to enter into any agreement which prevents open publication or restricts access, and that basically IP rests with the universities. Another respondent claimed that a two year gap between the research project and publication of findings is normally acceptable to most companies because in many cases it is not so much what appears in the journal articles but the know-how behind it that they are interested in. One interviewee said that they would ideally like to see a collaboration agreement that states:

> *'academics can publish because it's tax payers money, we want to spread the word as much as we can. But we want to see our Industry thrive and so we want to give them an appropriate lead, a lead time, so it's kind of a joint thing.' (0032)*

This respondent stated that their institution now insist that each project keeps an exploitation plan which is discussed each time the consortium meets. Several university interviewees indicated that IPR issues should be sorted out early on, either before or at contract negotiation. As pointed out by one respondent, IPR issues should be written into the original contract so that everybody knows exactly how the land lies. Another respondent stressed that IPR should not be addressed too late in the relationship because when the pound notes start appearing in people's eyes it gets more and more difficult. This respondent believes that the contract should always be done before the research starts and expressed that it should not be left to the academics because:

> *'... they need to be negotiating and agreeing with the company what the technical programme is all about. They shouldn't be bogged down in IPR issues. That should be done between the contracts people of the company and the contracts people of the university.' (0038)*

With regard to changes in a project's direction, this respondent mentioned that when preparing an agreement at the outset of a project, all the academics can say is that it is their best guess on how things should go based on their experience and expertise, but if changes happen, even between meetings, they should inform the industrialists. Other points raised by this respondent included the observation that academics should give industrialists the opportunity to decide whether a project should go ahead or not because they are paying for the work. Academics may, however, have a '*get out clause*' in the contract which enables them to close the contract if they think it is necessary to do so. Several other university interviewees also indicated that everyone involved in a collaboration should be kept up to date and informed of any modifications that are made or any new developments. One of the interviewees expressed that it is very important to have good mechanisms in place to enable any changes to the program to be properly managed. Another interviewee stated that if an ongoing relationship is desired you have to learn to manage that adaptability. One research council interviewee pointed out that some flexibility in some of these projects is a benefit, but is a recipe for conflict if changes to the project are needed later on. Consequently there is a need for '*structuring-in time for review, reflection and redirection*' (0028). A different respondent mentioned that the issue of flexibility or adaptation should be discussed at the outset of collaboration. This respondent also stated that for the majority of their grants, the participants are free to change the direction of their research but they are expected to justify it.

With regard to the management of expectations, although one of the research council interviewees mentioned that they find this aspect of collaborative research a bit of a challenge, one of the university respondents claimed that it is now improving (by mutual understanding). Another respondent stressed that there is a need to be more transparent about what our expectations of our partners are, to reduce some of the tedious or worse levels of negotiation. Two of the university respondents mentioned the use of a portfolio approach to collaboration structuring where a range of interaction formats are available that companies of all sizes can select from. According to one respondent, such a portfolio should include a range of products and channels for business to interact with within the university and provide information on what each one will achieve, what the timescale is, how much the collaboration will cost and what the benefits to the industrial partner are.

Pertaining to who should manage collaborative projects, one research council respondent claimed that they prefer industry to take the lead because experience has shown it works better that way, perhaps because industrialists generally have a more robust style of project management. Another respondent pointed out that the choice of who should manage a project is highly dependent on the individual groups that are involved. According to this interviewee there are some Faraday partnerships that are led by academics rather than industry and which are successful. In contrast to what the research council respondent stated about industry being better project managers, one of the university interviewees gave the following statement:

> *'... I don't think you can assume that a company is better at it than a university... it's a widespread, a mistaken assumption that just because somebody has worked for many years in an industrial company, that they understand industry. Within that company their role might have been limited, they may have benefited from the success of the company rather than being the cause of it, and very often they are brought from industry*

as a token industrialist and a bit of a disaster when advising a small company, or a university, or the government.' (0039)

A different interviewee interestingly revealed that most of the people responsible for industry-academia collaborations are men, and men are not as good at relationships as women are, as the following statement shows:

'Women have a typically greater empathy and sensitivity in managing relationships, they are better at it than men are. Men, as a gross generalisation, tend to focus on the outcomes and are slightly impatient with the human aspect of the process.' (0026)

The use of 'relationship managers' was mentioned on a number of occasions by the university respondents. One respondent claimed that it is useful to have a relationship manager at each end (i.e. one on the academic side and one on the industrial side) who have the task of meeting regularly, exploring how the relationship is going and looking for ways of broadening and deepening the relationship. The relationship manager at the industry end would also be administering the pot of money, scouring money out of the organisation and selling projects, whilst their counterpart on the academic side would be identifying which academics or which departments have the relevant skills, bringing them to the table and encouraging them to propose projects that are of relevance to the relationship. Two other interviewees discussed the use of 'client' or 'customer' relationship managers. According to one respondent, customer relationship management is about:

'... making sure that the relationship is working well so that at the end of that project it isn't a question of 'Oh that project's finished we'll go our separate ways'. It's intended to be part of an ongoing relationship. So it's about building relationships with our key corporate clients.' (0034)

The second interviewee claimed that if you client manage relationships correctly, you can have a relationship lasting 15 or 20 years and gave the following statement:

'... if you maintain that relationship in a way that suits the company they should always come back to you. So providing you deliver what they require and you are getting what you want out of it as an institution, why

> *should they need to go anywhere else if you have the expertise they are looking for.' (0038)*

According to this respondent, many universities are appointing client relationship managers. Concerning who should manage collaborative relationships, this respondent pointed out that not all academics are the same, so some will be better managers than others and therefore it may be more appropriate for a school, a group or the central university to manage it. But somewhere in the university there needs to be responsibility taken for 'Client A' so that the relationship is maintained. Whether the collaboration should be led by a university, by academics or by individual schools within the university depends on how the university is structured. One interviewee claimed that it is better to have people in both organisations (i.e. university & industry) whose job is to promote such relationships, for example relationship champions with professional and consultancy skills. Another interviewee who also mentioned the importance of having a person involved who makes sure that meetings happen and that review reports are written, stated that they would prefer it to be someone from their business development team. A different interviewee who indicated a need for facilitators, or facilitating organisations (e.g. technology transfer offices or research services offices), managing the relationships, referred to them as '*the buffer in the middle*' (0030). The companies can talk to these facilitators who understand their issues and who can then pass the information on to the university, having translated and filtered out what might be clearly provocative, and vice versa.

One example of a collaboration scheme which conforms to this model is the Faraday Partnerships which have an intermediary organisation familiar with both academic and industrial scenes. They act as an interface for information and people flow. One respondent indicated that industry-academia relationships are improving at those universities which employ people who act as an interface and who understand the legal issues, know what both sides are expecting, and can see where the pitfalls might lie. This respondent gave the following statement about the advantages of having facilitators and champions:

'... certainly the case with large scale collaborations, an independent facilitator is a wonderful thing, because you then get over the problem of the egos again. But having a champion within a company is sort of a fast track to easy collaboration.' (0035)

There have also been indications from other interviewees that energetic people like champions can help manage collaborative projects. Two respondents cited that it is important that they (industrial liaison managers) progress and maintain contact with the relationship. One of them keeps in touch with the collaboration participants on an informal basis and also acts as an additional point of contact, which is valuable because sometimes the participants find it difficult to get in touch with or to communicate with each other. One respondent stated that top management commitment to a collaborative relationship is important and that a collaboration will not work if it is organised at too low a level in the company or university.

4.3.6 Communication

Many interviewees emphasised the significant role played by communication in collaboration and the importance of maintaining communication to ensure a strong and ongoing relationship. Face-to-face communication (personal contact) was considered very important but, as indicated by one respondent, preferred and effective means of communication depends on the people involved:

'... some people will take hours to discuss the most simple of things and other people are very good at having, you know, an essentially bullet point communication.' (0023)

There were some indications in the interviews that initial face to face meetings make it easier to use other methods of communication afterwards. As pointed out by a university respondent, face to face communication is rather labour intensive but it is worth it in the long run. According to a different respondent the more you can get people talking face to face the better. This way you can build up and strengthen the interpersonal relationships within networks and have an exchange of tacit knowledge. Emphasis is more easily brought across in face-to-face meetings and it is also easier to reach agreements about ways forward by getting everybody together. Another interviewee mentioned that project meetings are milestones, but as one university respondent pointed out, the other forms of communication are useful to keep communication up after meetings, otherwise you can get '*sucked back*' into your work pattern. This respondent believes that the more meaningful links are more likely to be realised at networking events:

> *'You go and you really do network and you really do talk in as much technical depth as I am able to because I am not a computer scientist...' (0033)*

There is no clear answer from the interviewees in terms of which type of participant (industrialists or academics) may prefer to use which form of communication. Some respondents have, however, mentioned that academics do tend to use email because it is easier and quicker, and they have been using this format for a long time. One university interviewee stated that people seem to like email mostly because it is independent of time and place, but there is a risk that it substitutes for thought. According to this interviewee, everybody tends to write in the same format, whether the subject matter is trivial or significant. A research council interviewee also mentioned that sometimes people tend not to think of how they are using email because it is so easy. But, a different university respondent maintained that academics are more likely to want to think about their response to anything and so email is a much better provider for that environment. Some European projects function mostly via email because of its immediacy. Another university interviewee believes that projects can survive by email alone as long as the people involved are email literate.

There were mixed views from respondents with regard to the use of the Internet for communication. Some interviewees have encountered problems with the technology when trying it out. According to some respondents, people are not yet familiar enough with the technology. People can however be educated to work with it and one university respondent believes that the Internet will become more useful as the technology becomes more familiar. Another university interviewee speaking in the context of the use of different forms of communication in collaborations claimed that for making first contacts, the Internet, literature and things like that are always helpful but in their experience they have never generated any meaningful leads, not for things like research projects. As stated by a different university respondent, people lose some content for the sake of form on websites and one of the research council interviewees mentioned that the Internet has a risk of being *'impersonal'* (0028). The Internet is potentially a problematic form of communication for industry because they do not like to show or share their information publicly.

Video-conferencing was revealed to be a very valuable tool by two university respondents, especially if you cannot meet in person, particularly for long distance communication. One respondent mentioned that video-conferencing helps because you can see participants' reactions and also hear the nuances in what they are saying. The other interviewee stated that video-conferencing is becoming more and more routine as people recognise the amount of time, effort and money they can save by using this method, but pointed out that you cannot always rely on it because you *'need that kind of touchy feely aspect' (0024).* With regard to the use of the telephone, one university interviewee believes that small companies are more inclined to use this method because they want quick answers. There were several indications that the telephone is good for one to one relationships, whereas face-to-face meetings are best where more than two people are involved. The telephone has been cited to be the next best thing to face to face meetings and is useful if people need some encouragement or help. Finally, electronic communication is evidently more commonplace nowadays and some respondents indicated that paper is not used much any more, so as pointed out by one university respondent, if you do not read your email you will not know what is going on:

> *'... we used to send out vast amounts of paper to people who contact us, and now hardly anybody writes in. Everybody seems to communicate to us electronically. Clearly the academic side is well geared up for it, but increasingly the industrial side as well.' (0032)*

4.3.7 Best Practice advice

Quite a wide variety of responses were provided by the respondents when asked what should be contained in a document providing best practice advice for industry-academia collaboration. There were however, four issues that were frequently cited, these were: i) mutual understanding of objectives; ii) effective communication (e.g. keep it regular or open); iii) clarity of objectives and needs; and iv) effective management (e.g. suitable project management structure). Having flexibility and suitable or realistic funding or budgets were also commonly stated best practice factors. There were no clear differences in what the respondents from the different types of organisations (i.e. research funders & university centres) stated. Interestingly just one interviewee referred to best practice documents already published by organisations such as AURIL (Association for University Research & Industry Links). This interviewee mentioned that some of these documents are very good and help both sides better understand each other's perspective and what prospective tensions might emerge. Some respondents noted that industry-academia relationships need to be nurtured like any relationship and this is emphasised in the following statement given by a university based respondent:

> *'... remember that this is about relationships and not commodities. It's not about pile high and sell cheap, it's about relationships which take time to grow, which are infinitely valuable, which are not totally robust and so put in place mechanisms that will be sustainable...' (0026)*

Several interviewees stressed that the time required to set up a successful collaboration should not be underestimated and that the partners need to be realistic about the costs of collaboration. One research council interviewee stated that the key lesson they have learned from research collaboration is that *'it's horses for courses' (0031)* and you have to accept that not everything will work in any situation. Having relationship managers was thought to be an interesting good practice by a university respondent who claims that:

> *'It takes the heat out of it and keeps the relationship alive.' (0029).*

A different university interviewee maintained that good project champions are quite important and suggested that good people should be identified on both sides. According to one research council respondent, personal synergy is more likely to lead to something that is useful downstream. This respondent gave the following statement:

> *'If you decide you don't like an individual, I don't think it's even worth contemplating collaborating with them...' (0036)*

One university respondent emphasised the importance of mutual trust and respect, and nurturing the factors that give rise to it. The two key factors for many activities in collaboration are evidently communication and clarity, which is what one university interviewee particularly indicated. These factors in turn help achieve mutual understanding, the discussion of objectives and plans, and also help keep everyone informed. With regard to communication, one research council interviewee interestingly stated that collaborators need to:

> *'... be willing to ask what you think might be silly questions...' (0027)*

With regard to management, one university respondent maintained that it is best to try and avoid having complicated agreements in place and that some flexibility in how agreements are adapted to suit particular companies is required. Another university respondent pointed out that management is an ongoing process and one that should be overt. Finally, here is what one research council interviewee stated is important to note about collaboration:

> *'...it's not a linear process. There is not just a series of steps that automatically happen for any given situation... It really is, we do have to remain flexible, we do have to be proactive.' (0031)*

4.3.8 Summary of interview survey results

A wide variety of attitudes and options regarding industry-academia collaboration have been explored in the seven preceding sub-sections. The use of this information however needs some critical evaluation of the main or significant points. The findings of the interview survey are therefore summarised as follows:

1. Mutual benefits are important in collaboration. Industrialists are generally motivated by access to knowledge and facilities (especially students) at universities. Academics are mainly motivated by money (for research) and developing their reputations. The two main motivations for involvement in collaborative networks were identified as meeting people and knowledge exchange.
2. Organisational culture is an important factor in industry-academia collaboration, in particular the difference between academia and SMEs (small & medium sized enterprises). This appears to be changing as universities become more business oriented in their own activities. Many academics seem to be becoming less isolated and more entrepreneurial, but this is certainly not true for all of them. Because of the risks of collaboration, SMEs are more reluctant to be involved than larger companies are.
3. Jargon use across the industry-academia interface appears to be more of a problem than across disciplines, but this depends on the type of sector involved (i.e. pure v. applied).
4. The management of intellectual property rights and expectations has improved in recent years and many of the issues thought to be barriers are not insurmountable, i.e. they are increasingly considered as 'hurdles'.
5. A wide variety of factors that encourage or stop collaboration were raised by the interviewees. Having valuable or concrete outcomes and enthusiasm were important success factors, and personality clashes and change of personnel were significant breakdown issues.
6. There was a variety of opinions as to who should or is best placed to manage collaborative relationships, but the role of relationship managers, champions or facilitators came across strongly and there have been some indications that it is best not to leave responsibility for management to the academic side. Many respondents stated that there should be a management or steering group that meets regularly.

7. To ensure that relationships last, respondents suggest that someone in the university be responsible for handling or managing the client (industry). This is not the same function as managing the research activity itself but it may be carried out by the same individual.
8. With regard to collaboration agreements or model structures, there was a variety of opinions as to whether a formal or informal management structure is best, but it appears that one size does not fit all. More structured approaches appear to be best for larger and international collaborations.
9. It is important to have at the outset (or before) a clear written collaboration agreement and a common understanding of what is expected and what is to be done. Having an adaptive or responsive style to project management is also seen as important.
10. Four key issues were highlighted in relation to the management of industry-academic relationships: i) intellectual property rights (IPR), ii) expectations, iii) exploitation, and iv) modifications to a project's direction.
11. With regard to the evaluation of industry-academia collaborative schemes, most respondents, particularly those from the research councils, consider it a problem particularly the measurement of softer (subjective) metrics and long term impact, but it is not intractable.
12. On the subject of communication, maintaining communication and organisation of face-to-face meetings are fundamental to any relationship. Face-to-face communication also facilitates the use of other methods of communication after initial meetings. Electronic communication is now more commonplace but some people have had mixed experiences with using the Internet because they are still not familiar enough with the technology.
13. Referring to best practice, again there was a wide range of responses but many respondents emphasised the importance of shared understanding and trust. Clarity of objectives or needs, regular

communication, flexibility and suitable (realistic) funding were also frequently mentioned.

4.4 Summary

This chapter has described the design, deployment and analysis of an interview survey carried out with sixteen individuals that facilitate industry-academia collaborative research schemes in the UK. The scoping (or 'pilot') interview carried out prior to the main interview survey proved to be useful in removing the uncertainties associated with the design and conduct of the fieldwork. Scrutiny of the data obtained from the scoping interview identified a number of issues which were taken into account when designing the template for the main interviews, including that the interview questions should be semi-structured to ensure responses are related to defined topics of interest and to facilitate data analysis.

The findings of the interview survey show, in general, that industry-academia research collaboration is a process characterised by sectoral and also individual variations which may influence success. There is also a variety of types of relationship. The findings help inform the conceptual model described in Chapter 3 by describing the structure of different types of collaboration, for example, size, duration, formality (i.e. informal or formal), funding, etc. and a variety of mechanisms adopted or perceived (by the research facilitators) to be appropriate in managing these types of collaborations. The interviewees also provided information on the different attitudes of industrialists and academics, including their motivations, expectations, organisational cultures, as well as the variety in attitudes of institutions within different industrial sectors (e.g. pharmaceutical & manufacturing) or fields of research (pure & applied). The differences between small and large companies were also highlighted, and there is evidence that the cultures or attitudes of academics are changing. The survey also acquired information on the collaboration process, in particular in terms of barriers being overcome with time ('hurdles') and what factors can help maintain the collaboration process or can cause a relationship to breakdown.

The collaboration process is clearly influenced by the management approach adopted as well as communication (as described in Chapter 3 for the conceptual model). Valuable or concrete outcomes (at different stages) or regular feedback can help maintain the relationship in terms of keeping the participants enthused. Many of the comments made during the interviews (including the scoping interview) appear to be based on experience and there seems to be a lot of 'learning by doing and/or observation' going on. Only one respondent referred to best practice documents published by other professional organisations and just one interviewee referred to a 'model' agreement on the government's LINK scheme website. Prior experience of collaboration is believed to help collaboration, particularly in setting up agreements and managing the collaborative process.

However, the elicited perspectives of the collaborative research facilitators need to be tested, particularly in terms of the collaboration process (barriers & communication) as well as the attitudes (& motivations) of the various participants, as many of the facilitators are not involved at the 'coal face' of collaborative projects or networks (some are involved only at the start of the relationships). As indicated in Figure 4.1, the results from the interview survey were used to guide the next core research activity; a questionnaire based survey of EngD (Engineering Doctorate) and CASE (Co-operative Awards in Science & Engineering) students working on projects jointly supervised by academics and industrialists. In this survey, we will explore how the various issues that emerged in the interview survey actually impact collaborative research projects. This activity is described in the following chapter.

5. Research Activity – Questionnaire survey of students involved in collaborative research projects

This chapter describes the second fieldwork activity; a questionnaire survey of Engineering Doctorate (EngD) and CASE (Co-operative Awards in Science & Engineering) students who are working on projects jointly supervised by academics and industrialists. The general objective of this survey is to obtain and analyse the perceptions of students on their experience of industry-academia collaborative research. As the students are at the 'coal-face' of collaborative research, obtaining their perspectives allows us to explore the collaborative process from an experiential point of view. Their perceptions will be compared with those obtained from the collaborative research facilitators involved in the first survey (Chapter 4).

The EngD programme which is organised by the EPSRC (Engineering & Physical Sciences Research Council) is a four year postgraduate studentship focused on commercially relevant research and including an MBA training course. The EngD was first introduced in 1992 in response to the needs of industry and demand for more industrially relevant qualifications coming from students (EPSRC, 2002). EngD students (known as 'research engineers') are expected to spend around 75% of their time working directly with the collaborating company. The project (or a portfolio of projects) is designed by an academic institution and a co-operating company (or, indeed, companies), who jointly supervise the studentship.

The CASE scheme is supported by five UK Research Councils, EPSRC, PPARC (Particle Physics & Astronomy Research Council), NERC (Natural Environment Research Council), BBSRC (Biotechnology & Biological Sciences Research Council) and ESRC (Economic & Social Research Council). Most CASE projects are also designed and supervised by both an academic institution and a collaborating company. Some CASE projects are defined only by the industrial partner who then selects the academic partner, and then both partners select and supervise the student (e.g. EPSRC Industrial CASE). CASE students are usually working towards PhDs and, to qualify, they need to spend at least 3 months of their three year project (except for part-time students) working in an industrial setting with the collaborating company. The 'industrial' partner can be any organisation in the public or private sectors, including charities, local authorities, and research council institutions or laboratories. According to Stewart (1999):

> *'CASE has been a very successful mechanism, using the postgraduate student as a carrier for moving complex scientific skills across the knowledge 'frontier' between industry and university.' (p. 164)*

Both the EngD and CASE schemes offer students the opportunity to undertake a research project with both practical and theoretical aspects and to gain experience of working in both industrial and academic environments.

As indicated in the previous chapters, the findings of the interview survey have been taken into account when designing the template for the questionnaire survey and this is detailed in the first section (5.1). The following section (5.2) describes the practical aspects of survey management including how the students were accessed and the questionnaire was distributed, how the responses were received and stored, and what techniques were used to analyse the responses received. In Section 5.3, the results of the student survey are reported and related to issues that emerged from the interview survey (Chapter 4), and the scoping studies (Chapters 2 & 3). The primary results of the questionnaire data are presented in Appendices 5D, 5E and 5F.

5.1 Design & piloting of questionnaire template

In Chapter 3, it was explained why a questionnaire was selected as the most appropriate technique for eliciting students' perspectives on industry-academia collaborative research. The issues that are involved in the design of a questionnaire template, particularly the choice of questions to use, were also discussed in detail. It was also made clear that the design of the questionnaire has been based both on the research questions and on key issues or findings that emerged from the interviews with the collaborative research facilitators; in order to compare the perspectives of the two response groups. It is evident from the interview survey results reported in Chapter 4 that some of the themes are not relevant to the students as they assume an experience of several projects or networks, or are focused on collaborative research schemes/programmes rather than individual projects (Section 4.3.3 – 'general' sub-section). They also assume an experience of evaluating collaborative research projects or networks (Section 4.3.4). The themes that are relevant to the students include:

- the motivations of industry and academia to participate in collaborative research projects;
- benefits that both partners gain from such projects;
- barriers or problems that are encountered in collaboration;
- the nature and effectiveness of collaborative projects in terms of 'good' or 'bad' characteristics;
- suitability of different project management structures;
- modes of communication;
- best practice for collaborative research projects.

The design of the questionnaire template is motivated by the desire to answer two key questions:

i) What are the determinants of a successful collaborative research project from the perspective of research students?
ii) How do the various issues raised by the collaborative research facilitators impact project success?

The questionnaire template is shown in Appendix 5A which has a table on the first page showing the theme and sub-topic that each question in the questionnaire aims to acquire information on. Some of the questions are designed to characterise the student, their project and both the industrial and academic partners (supervisors) involved in the project. Most of the questions are focused on a set of possible influences on the collaborative project that were identified from the interview survey (Chapter 4) and the scoping studies (Chapters 2 & 3). For example, the supervisors' enthusiasm for the project, compatibility of the supervisors' disciplinary backgrounds, prior collaboration experience, personnel changes, change in project objectives, collaboration agreements, problems with timescales and communication problems. For the industrial and academic motivations for collaboration, a number of statements describing motivations identified from the interview survey are listed, and the students were asked to rate how true they believe them to be in the case of their project (see questions 10a & 10b, Appendix 5A). For the benefits that the industrial and academic partners gain from the project, the students were asked to list three benefits for each side (questions 11a & 11b). Several comment boxes were also included in the questionnaire template to enable students to make comments on any other problems they have encountered in relation to the collaboration as well as provide suggestions to help improve collaborative research (questions 36, 41 & 42).

The survey also took the opportunity to look at the influences of different factors (e.g. personnel changes) and relative success at different points in the project lifecycle (using year of project). The students' impressions of success is the measured variable here and a multi-variable measure of 'success' was constructed from responses to the following questions (with their corresponding numbers in the questionnaire, see Appendix 5A):

Qu. 38 *How would you measure the success of the collaboration personally, for the industrial side and for the academic side?*

Qu. 14 *How satisfied are you with your project's progress?*

Qu. 39 *To what extent are you enjoying your research work?*

Qu. 40 *Since you have started do you feel that the relationship between the two parties has improved or worsened?*

Response options to the first of these questions (Qu. 38) were divided into three 'rating' (Likert) scales (1 'low score' to 5 'high score'), each one for: i) personally, ii) the industrial side, and iii) the academic side. These 'scale' variables enable success 'means' to be calculated for groups of cases influenced by a particular factor, and therefore t-tests to be carried out to indicate whether the means are significantly different or not. The second and third questions (Qu. 14 & 39) above were designed as 5 point 'ordinal' Likert scales (i.e. 1 = 'not at all satisfied' to 5 = 'very satisfied'). The fourth question (Qu. 40) is designed as a categorical or 'nominal' question (i.e. 'improved', 'worsened' or 'not sure').

Two questionnaire templates were designed; one for EngD students (as shown in Appendix 5A) and another one for CASE students - all the questions in both templates are the same, only the wording referring to the type of studentship is different (i.e. 'CASE' & 'EngD'). An online questionnaire was selected as the most appropriate elicitation vehicle for the following reasons:

i) It is quicker to distribute than by post – a hyperlink (URL) can be sent to the respondents by email – they just need to click on the link to access the questionnaire;
ii) It is easy to complete – particularly for the closed type questions where you just need to click on the appropriate buttons;
iii) The respondents do not need to post their responses back, they just need to click on a 'submit' button and the responses are received immediately by email;
iv) The responses are already in text or number format and just need to be copied and pasted into a database.

The questionnaire template was first designed within a word processing package so that it could be piloted to ensure that respondents understand the questions and provide responses in a suitable and anticipated format. The pilot questionnaire was completed by five EngD students. No major problems were encountered in the pilot study and the students provided satisfactory responses and feedback. The only significant change made was changing the Likert scales from 4-point to 5-point scales as they were believed to provide insufficient response options without a neutral central point on the scale. Once the final changes were made, the template was created in an HTML (HyperText Markup Language) format (as shown in Appendix 5A). The HTML template was then uploaded onto a web server which runs a 'generic form process' program that enables the entries made on the webpage to be automatically received by email. All the questions, the text boxes (for open-ended responses) and the 'radio' buttons (for closed-type questions) on the HTML template had their own labels so that the 'response' email shows the question labels and their corresponding answers together.

At the top of the questionnaire template information was provided on the purpose of the survey, the organisations that sponsored and conducted the survey (EPSRC & Cranfield University) and why respondents (the students) have been asked to complete the questionnaire. Instructions were also given as to how to complete and submit the questionnaire. The students were assured that all responses received would be kept strictly confidential. Anonymity is preserved and the ethical guidelines on research practice laid down by both Cranfield University and the British Psychological Society are conformed to. The next section describes the activities carried out in gaining permission to access the students, distributing the questionnaire, collecting and storing the responses and analysing the data.

5.2 *Questionnaire survey - Description of activity*

5.2.1 Communication & Distribution

In order to secure permission to distribute the questionnaires to EngD and CASE students, emails providing information on the purpose and objectives of the survey were sent to individuals responsible for these schemes at five of the UK Research Councils (EPSRC, BBSRC, PPARC, NERC & ESRC) and at fifteen Engineering Doctorate Centres. Permission was granted by all five Research Councils and 13 of the 15 EngD Centres (there was no response from 2 EngD centres). Ten of the EngD centres offered to distribute the questionnaire themselves and three centres provided email addresses for their

EngD students. One research council offered to distribute the questionnaire to their CASE students and three of the research councils provided databases containing the names, department and institution of the academic supervisors holding a CASE award. The email addresses for these CASE academic supervisors were searched on the relevant university websites. One research council provided a list of companies that they allocated Industrial CASE awards to, with contact names and email addresses.

A contact database was developed containing the names and email addresses of all the individuals (EngD centres, EngD students & CASE supervisors) that the questionnaire could be sent to. An email containing a covering letter indicating the purpose of the survey and providing a URL link that could be used to access the questionnaire was sent to all the contacts. If the contact was a CASE supervisor or an EngD centre, the email asked the individual if they could forward the email to their student(s) (Appendix 5B). These emails were distributed in November 2003 and a reminder email also sent after the Christmas break at the beginning of January 2004 to chase up responses. The questionnaire was removed from the web server at the end of January 2004.

A few CASE supervisors and students enquired about the term 'industry' on the questionnaire (in particular ESRC & NERC funded CASE) because their 'industrial' partner was either a charity or a government organisation (e.g. local authority or research institute). They were informed that the term 'industry' was to be understood as indicating any non-academic organisation. Some of the supervisors that received the email responded to say that they did not have a CASE student. Also a few first year students mentioned (either by email or on the questionnaire) that they considered it premature in terms of their experience of collaborative research for them to complete the questionnaire as they had only just started their project and therefore some of the questions were not applicable to them. Because of these comments and mainly because it was not certain how many supervisors actually forwarded the email to their students, there were difficulties in estimating the response rate for the questionnaire survey. Table 5.1 shows the number of responses received following the initial and reminder emails and the estimated number of students who received the questionnaire (based on the number of students contacted directly & the average number of students associated with each contacted CASE supervisor & EngD centre - it is known that 6 EngD centres forwarded the email) and therefore the estimated response rate.

Table 5.1: Questionnaire response rate

No. of responses received	
No. responses received after initial email (Nov. '03)	257
No. responses received after reminder email (Jan. '04)	91
Total no. responses received	**348**
(of which 64 from EngDs & 284 from CASE students)	
Estimated no. students received questionnaire	
EngD students	220 – 250
CASE students	1110 – 1310
Total	1330 – 1560
Estimated Response rate	**22% – 26%**

It is not possible to estimate how representative the estimated response rates are of the total EngD and CASE student population because it is difficult to calculate the total number of students currently signed up to these studentships. The majority of the responses were from final year students (3^{rd} year CASE (41%) & 4^{th} year EngD (36%)) students; perhaps suggesting that the final year students were more confident about completing the questionnaire because they had more experience of collaborative research. The CASE responses involved 59 different academic institutions and just over 170 different industrial or non-academic organisations (~65% private companies; ~35% government - including research centres & charities). The EngD responses involved 10 different academic institutions (9 EngD centres) and just over 50 different industrial companies. This enables us to explore collaborative research in a wide variety of academic fields and industrial sectors.

5.2.2 Data collection & storage

All submitted responses to the questionnaire were received by email. Hard copies of all these emails were made for backup purposes and these copies will be stored until the end of the project. The emails were destroyed once all the data were transferred to a database. The responses were copied and pasted into a word processor where a macro was created to convert the data into a table with the question labels placed in the left column and the corresponding responses placed in the right column. The data in the right column (responses) were then copied and pasted into an Excel database. An ID code was created for each student and to ensure that anonymity is preserved, the students' names, which enabled us to roughly estimate the survey response rate and to ensure that no duplicate replies are received, were not included in the databases.

While the data was being collected and stored, a coding sheet was created for the answers to the closed-type questions (see exemplar codes for database 1, Appendix 5C). Once data collection was completed (when the questionnaire was removed from the web server), all the responses to the closed-type questions were coded in the Excel database. These coded responses were then copied and pasted into an SPSS (Statistics Package for Social Sciences) database for analysis (Appendix 5C shows the variable names & labels for database 1). The next section describes how these coded responses (quantitative data) were analysed and how the responses to the open-ended questions (qualitative data) were coded and analysed.

5.2.3 Data analysis & initial results

The quantitative data were first analysed using descriptive statistics which produces basic frequency tables – these tables are provided as Appendix 5D. Then for the 'ordinal' Likert scale responses, the modes were calculated, which indicates the most common answer. Using the mode as a single summary value for ordinal Likert scale data is believed to be more appropriate than the 'mean' (average value) because the intervals between the numbers on these types of scales are not necessarily equal. The means can however be calculated for the 'scale' Likert scale variables which are based on a score of 1 to 5. Appendix 5E shows the calculated mode or mean for all the responses to each Likert scale question. Comparisons are then made between the means of the variables used to evaluate 'success' (as well as the 'overall' project success which is the sum of the scores for the three 'success' variables) for particular groups of projects influenced by a certain factor: for example, projects that have encountered personnel changes versus those that have not. This is carried out by calculating the subgroup means. The independent samples t-test procedure is also used to compare the means for two groups of cases to test whether the means are significantly different or not (i.e. to test the influence of a particular factor on the project's success measures). Cross-tabulations were used to present data as two-way or multi-way/multi-layered tables to compare means or percentages across particular groups of cases.

The open-ended responses to the questions about the students' motivations for doing their project, the benefits that the students personally gained from each side (academic/industrial) whilst carrying out their projects, and the benefits that each partner institution (academic/industrial) gained from the projects (questions 7, 8 & 11 in the questionnaire respectively, see Appendix 5A) were all copied and pasted into tables created for each question in a word processor. These tables were all read through carefully several times and a list of categories was created for each question (see categories for database 2 in Appendix 5C). The responses were then coded according to the category lists and the results were quality checked by a colleague. Once this was completed, the coded responses were put in a new SPSS database (database 2). The results were analysed using the 'multiple response frequencies' procedure where the several variables for each question can be defined as a set and which calculates the total number of times each category is mentioned as well as the percentage of cases (students) that mentioned each category (see Appendix 5F).

The students' responses (or comments) to open-ended questions related to the following topics were all also copied and pasted into tables:

- unexpected benefits (Qu. 12a)

- differences between the industrial and academic partners which cause problems when carrying out or reporting on the project (Qu. 19a)
- other problems which they have encountered in relation to industry-academia collaboration (Qu. 36)
- process or experience of industry-academia collaboration (Qu. 41)
- suggestions to help improve collaborative research (Qu. 42)

Each table was carefully read to identify common themes and the relevant segments or sentences were cut and pasted into sub-tables corresponding to each theme (Appendix 5G). Quasi-statistics were used to calculate roughly the number of times each theme was mentioned (the five most frequently mentioned topics for questions 19a, 36 & 42 are shown in the next section).

There are many ways in which the questionnaire survey data can be analysed and interpreted but it must be remembered that the research described in this thesis is based on a particular research agenda or framework (as described in Chapter 3). Therefore the questionnaire data was analysed based on a list of additional research questions emergent from the interview survey (Chapter 4), the scoping studies (Chapters 2 & 3) and the primary results (Appendices 5D-F). These questions are specified under each sub-section (representing different themes of the questionnaire survey) in the next section which shows the results of this analysis.

5.3 Questionnaire survey - Results

The results from the questionnaire survey of EngD and CASE students are presented in the same thematic order as the results of the interview survey (with the exception of that relating to evaluation which is not applicable here) as follows:

i) 'Motivations' for and 'Benefits' of collaboration (for the industrial & academic sides);
ii) 'Barriers' and 'Problems' in collaboration;

iii) 'Nature and effectiveness' of collaboration (in terms of characteristics of 'successful' and 'unsuccessful' projects only, not collaborative schemes);
iv) Project 'Management';
v) Modes of 'Communication';
vi) 'Best practice' advice.

There are also three additional thematic sections: the first one looks at 'sectoral' variations (i.e. variations in the success of collaborative projects in different fields of research), which is a theme that emerged several times during the interview survey (e.g. Section 4.3.2 (iv), Chapter 4); the second section looks at data related to the students, including their role in the project, their industrial knowledge and experience; and the relationship between their age and perceptions of collaboration success. The final section compares the responses of CASE students with their EngD counterparts. The additional or 'specific' research questions emergent from the interview survey, the scoping studies and the primary results are shown under the first paragraph of each section representing each theme or aspect of the survey (or a sub-topic related to a particular theme). Conclusions relating to these additional questions are provided in the same section that the questions are posed in.

5.3.1 Motivations & Benefits

The motivations listed as response options in the student questionnaire were taken from the list of motivations provided by the collaborative research facilitators during the interview survey. The students were asked how true these motivations are in the case of their own projects. They were also asked to list three benefits that each side (academic & industrial) gains from the project. In both the literature and the interview survey, the most important identified benefit to industry of collaborative schemes was found to be access to students and the opportunity to evaluate them as potential employees. The schemes allow companies to have a student without long-term commitment. Other identified benefits include access to trained researchers and tacit knowledge. The specific questions to be addressed by this aspect of the survey are:

- *Do the students also believe that those motivations identified by the collaborative research facilitators are relevant for industry/academics?*
- *Do the perceived benefits match the perceived motivations?*
- *How do the students' responses on the benefits of collaborative projects to industry compare with those mentioned in the literature?*

The answers to these questions are provided in the next two sub-sections. Data on the motivations and benefits of industrial partners are explored first in the first sub-section below and those for the academic partner are described in the second sub-section.

i) Industry's motivations & benefits

Respondents gave very diverse answers to the question on motivations for industrial collaborators. The most frequently mentioned industrial motivation amongst the collaborative research facilitators was 'access to academic knowledge or expertise'. Forty-six percent of the respondents in the student survey believed that the industrial motivation 'to extend their knowledge base' is 'very true' (mode = 5, see Table 1, Appendix 5H). On the other hand, financial drivers, whether the company wants to make money or wants to avoid spending money on long term or riskier projects in-house, were mentioned several times in the interviews but 41% of students believed that the motivation 'to boost their sales or income' is 'not at all true' (mode = 1). Another motivation mentioned frequently in the interviews is 'access to university facilities or resources' and this is not considered by the students to be very significant (mode = 2).

The diversity of opinions regarding industrial partner motivations may be due to the fact that many students do not spend much time with the industrial partner (see table labelled 'time spend working at industry' in Appendix 5D) and therefore are not sure what their motivations are. This can be seen by looking at the 'uncertain' percentages in the primary results (Appendix 5D) which are higher for the industrial than the academic motivations. The 'uncertain' percentages by year of project and by the time students spend at industry are explored further in Section 5.3.8 (sub-section ii). Another reason may be the diversity of industrial partners, i.e. research centres, charities and private companies, which have different motivations for collaboration.

The students' responses regarding the benefits the industrial side gains from their project included 18 different types of benefit (see categories in Appendix 5C), of which 'access to academic knowledge or expertise', 'cheap research' and 'links or contacts with academics' were the three most frequently mentioned (Appendix 5F). Matching the benefits that the industrial side gains from the project with the motivations (Table 2, Appendix 5H), having 'access to academic knowledge or expertise' was the most frequently mentioned benefit and matches well with the motivation, 'to extend their knowledge base' which has a mode score of 5 ('very true'). Related to the motivation 'to raise their profile within society', which has a mode score of 4, 'prestige' was mentioned by just over 20% of the students as a benefit. Interestingly, 'cheap research or labour' is the second most frequently mentioned benefit but the motivation 'to avoid in-house investment' has a mode score of only 1. Having 'access to students' (to help with research or to access their knowledge/skills) is also an important benefit, having been mentioned by a quarter of the students. In the interviews, this was also stated to be an important benefit to industry of schemes such as CASE. Some of the respondents in the interview survey indicated that the chances that students stay in the company are very high and 'potential employees' was mentioned as a benefit by 15% of the students.

ii) ***Academic's motivations & benefits***

The majority of participating students believe that for the case of the academic collaborator, all the motivations mentioned by the collaborative research facilitators are 'true' (modes = 4 or 5; see Table 3, Appendix 5H). The most frequently mentioned academic motivation in the interviews was money and the motivation 'to generate income' is a 'very true' motivation according to over a third of the students (37%). In the students' responses on what benefits the academic side gain from the project, there were 19 different types of benefits (see categories in Appendix 5C), of which 'money', 'links or contacts' with industry and 'access to industry's facilities' were the three most frequently mentioned (Appendix 5F).

Matching the benefits that the academic side gains from the project with the motivations (Table 4, Appendix 5H), the most frequently mentioned benefit 'money' matches with the motivation 'to generate income' which has a mode score of 5. The benefits related to the student (student training & employment) have not been very frequently mentioned but the related motivations are quite important according to most students. 'Well trained students' was one of the benefits that emerged in the interview survey. In the interviews some respondents mentioned that there is a reverse flow with regard to access to facilities as some universities cannot afford state of the art equipment. Just over a third of the students mentioned 'access to facilities' as a benefit for the academic side, compared to just 19% for the industrial side, and this motivation has a mode score of 4 for academics, but only 3 for industry.

5.3.2 Barriers & Problems

In the survey of collaborative research facilitators, participants were asked questions about the barriers to or problems which occur during industry-academia collaboration. The issues perceived to be important in this respect according to the interview respondents were the right to publish, differences in timescales, intellectual property rights (IPR), negotiation in agreements, communication and company changes. In the literature review (Chapter 2) the most significant barriers or problems in collaboration were related to institutional differences (different cultures and structures), information dissemination restrictions due to confidentiality issues, intellectual property rights, and ineffective communication. In their study of six collaborative research projects involving doctorate students, Barnes *et al.* (2002) found that the students experienced difficulties as a result of unclear or frequently changing objectives, pressure to produce results quickly and industry's short term focus. In the questionnaire, the students were asked if there are differences between the industrial and academic partners which cause problems when carrying out or reporting on their projects, and to describe these differences. They were also asked to comment on any other problems which they have encountered in relation to industry-academia collaboration. Specific questions to be addressed by this aspect of the survey are:

- *What problems are encountered which are a direct result of institutional differences between the two parties?*
- *Are there any additional problems to those highlighted in the interview responses?*
- *Have the students encountered problems similar to those identified in Barnes et al. (2002)?*
- *Are projects where the objectives have changed less successful?*

Looking at the students' responses to the questions related to project timescales, communication, personnel changes, and compatibility of their supervisors' backgrounds; the percentage of students who encountered 'problems' related to those issues are listed below: *(ranked high to low % of all cases)*

i) 35% of students encountered problems with regard to project timescales
ii) 27% encountered communication problems with their supervisors
iii) 11% encountered communication problems between the partners
iv) 36% of the 90 students who encountered personnel changes in their coordination group stated that the change had an effect on their project
v) 31% of the 32 students who rated their supervisors' disciplinary backgrounds as 'poorly compatible' stated that this is a problem

In response to the question asking if there are differences between the industrial and academic partners that cause problems when carrying out their projects, 22% of the students responded 'yes'. In their descriptions of the differences between the partners, the five most frequently mentioned topics were: *(ranked in descending order of frequency (count))*

i) Different views or aims for the project's direction or outcomes (20)

ii) Different reporting styles or requirements (16)
iii) Publication or confidentiality issues (13)
iv) Industrial partner wants simple results and academic wants more detail (9)
v) Timescales or work pressures from industry (7)

The five most frequently cited topics mentioned in the students' comments on other problems which they have encountered were: *(ranked in descending order of frequency (count))*

i) Communication problems (16)
ii) Industrial changes (13)
iii) Different opinions or expectations (9)
iv) Administration or funding problems (9)
v) Problems with industrial supervisor (7)

Combining the results listed above, the most significant factors in the students' projects were different objectives or views, different timescales, and publication or confidentiality issues. Communication problems were also important, mainly with regard to a lack of or infrequent communication but jargon was also mentioned by two students. The influence of communication problems on collaboration success are explored further in Section 5.3.5. Several issues related to the industrial partner are also quite significant, in particular personnel changes. The influence of personnel changes on collaboration success is explored further in sub-section 'i' below. There were more problems identified which relate to the industrial supervisor (mainly a lack of input or interest) than to the academic supervisor. Different reporting styles or requirements is an issue raised by the students that was not mentioned by the collaborative research facilitators. It is also worth noting here that there were several comments from students who have encountered problems in relation to geographical distance between the industrial and academic institutions; some of these are shown in Table 5, Appendix 5H.

To find out if projects where the objectives or methods have changed are less 'successful', the 'success' means (corresponding to four 'success' variables: (i) personally (student), (ii) for the industrial side, (iii) for the academic side and (iv) 'overall') for projects where the objectives have changed are compared with those for projects which have not encountered such changes (see Table 5.2). The 'overall' success score is the sum of the scores of the three other success variables. The mean for this variable is calculated independently from the means of the contributing scores.

Table 5.2: Comparing the 'success' means by whether the project objectives or methods have changed or not

Changed project objectives or research methods?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Yes	Mean	3.75	3.28	3.70	10.72
	N	174	174	174	174
	SD	1.060	1.056	.921	2.483
No	Mean	3.77	3.48	3.74	10.99
	N	137	136	136	136
	SD	1.024	.927	.779	2.254

[N = no. of cases; SD = standard deviation)

The means are only slightly but consistently lower for projects where the objectives or methods have changed and a t-test confirms that the differences are not significant (sig. = 0.91 (personally); 0.08 (industrial); 0.63 (academic) & 0.34 (overall); the means are significantly different if sig. <0.05).

As shown earlier, nearly a third of the 32 students who rated their supervisors' disciplinary backgrounds as 'poorly compatible' stated that this is a problem. Exploring the effect of the compatibility of supervisors' backgrounds on the 'success' means (Table 6, Appendix 5H) revealed lower 'success' means where the supervisors' backgrounds are 'poorly compatible' (<3) and highest where their backgrounds are 'very compatible'. A t-test for low versus high compatibility using 3 as the 'cut-off point' (i.e. >=3 versus <3) indicates significant differences in all of the means (sig. = 0.00 for all 4 'success' means). Therefore the compatibility of the supervisors' backgrounds can be stated to be correlated with project success as perceived by research students.

Exploring the influence of project timescale problems on project 'success' measures (Table 5.3) shows lower success means for cases where problems have been encountered with timescales. A t-test demonstrates that the means are significantly different (sig. = 0.00 for all 4 success means).

Table 5.3: Comparing the 'success' means by whether problems have been encountered with project timescales or not

Encountered problems with project timescales?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.45	3.07	3.47	9.99
	N	121	121	121	121
	SD	1.088	1.006	.867	2.333
no	Mean	3.99	3.61	3.89	11.49
	N	187	186	186	186
	SD	.930	.895	.801	2.139

[N = no. of cases; SD = standard deviation)

The next three sub-sections explore three issues related to barriers or problems in collaborative projects, each of which have their own set of questions derived from the interviews, research background and primary results, as follows: i) personnel changes in collaborative projects; ii) measures of success over time; and iii) size of company.

i) Personnel changes

In the literature review, we saw that personnel changes are 'disruptive' in industry-academia collaborations and that company changes are more commonly associated with SMEs (small & medium sized companies) but large companies are also increasingly subject to changes. According to some respondents in the interview survey, personnel changes are more likely in new relationships and in collaborations with small companies which are more unstable than large companies. Earlier in this section it was revealed that 36% of the 90 students who encountered personnel changes in their coordination group stated that the changes had an effect on their project. The specific questions to be addressed by this aspect of the survey are:

- *Are personnel changes disruptive? (or can they be overcome?)*

- *Are personnel changes more commonly associated with small companies?*
- *Are personnel changes more frequent in new collaborations?*

Table 5.4 compares the 'success' means in projects where there have been personnel changes with those for projects which have not encountered such changes.

Table 5.4 Comparing the 'success' means by whether there have been personnel changes in the coordination group or not

Personnel changes in coordination group?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Yes	Mean	3.78	3.19	3.62	10.59
	N	90	90	90	90
	SD	1.014	1.016	.869	2.293
No	Mean	3.78	3.42	3.75	10.95
	N	227	226	226	226
	SD	1.025	.987	.864	2.389

[N = no. of cases; SD = standard deviation)

The 'success' means are lower for the academic and industrial sides in projects where there have been personnel changes in the coordination group, but for the student the means are the same. A t-test indicates that the means are not significantly different (sig. = 0.99; 0.06; 0.23 & 0.22 respectively). The percentage of companies who experienced personnel changes by size of company and by whether the partners have worked together before or not are shown in Tables 7 and 8 in Appendix 5H. There are no differences in the percentage of companies who experienced personnel changes by size of company and the percentage is only a little higher for projects where the partners have not worked together before. Most of the personnel changes took place during the first or second years of the students' projects (Table 9, Appendix 5H).

Looking at the comments given by some of the students who encountered industrial personnel changes, several mentioned that they are having problems liaising with other people in the company because they do not have the same interests or experience as their previous industrial supervisor. There were three cases where the students had three different industrial supervisors, all projects with large companies. Most of the personnel changes involve individuals leaving the company but a few changes were due to companies being bought-out or going out of business. Two students commented that although personnel changes are unsettling, it gives them flexibility in their research. One student stated that the 'relationship' for her project has 'worsened' solely due to the change in industrial personnel. Another student whose industrial supervisor left the company during his first year suggested that there should be '*standardised procedures for when supervisors leave the industry so that the student doesn't end up without a proper port of call within the industry that is working on the project too*'.

ii) Measures of success over time

In the interviews with the collaborative research facilitators, it emerged that many of the perceived barriers in industry-academia collaborations are 'hurdles' that can be overcome with time. One interviewee stated that cultural conflicts can be overcome if there is willingness, understanding and trust between the collaborative participants. The enthusiasm of collaborative participants is believed to be important for maintaining collaboration success as trust and understanding takes time to develop. In the students' comments on the problems that they have encountered, it was evident that some of the problems occurred at the beginning of their projects and that some problems were indeed overcome. One student commented that it '*takes a few months for all partners to understand what is expected or going on*'. Also, as shown in the primary results (Appendix 5D), the relationship between the two parties (industry & academic) has 'improved' over time for just over half of the students and the quality of communication has 'improved' over time for nearly two thirds of the students. Specific questions to be addressed by this element of the survey are:

- *Do the students' measures of their project's success vary significantly as a function of project duration?*

- *Is the percentage of students who encounter problems in relation to timescales and to differences between the partners independent of project duration?*
- *Does the partners' enthusiasm/understanding (of the project) have a significant influence on project success? Does it vary with project duration?*

The 'success' means are compared by year of project (i.e. the current year of student registration) first for CASE and then for EngD projects, because the duration of these projects are different (i.e. 3 and 4 years respectively). The students' satisfaction with their project's progress is also analysed over time using cross-tabulations.

The 'success' means are very similar for CASE projects in their second and third years but the means are lower for projects in their first year (Table 10, Appendix 5H). The second year CASE students seem to be less satisfied with their project's progress compared to first and third year students (Table 11, Appendix 5H). This could be due to 'mid term blues' where the students feel low half way through their projects compared to the start and end when they are more excited about starting and completing their projects. The third year CASE students are only slightly more satisfied than 1st year students.

For all but the industrial side, the perceived 'success' means are lowest for first year EngD projects and increase by year of project to the third year (Table 12, Appendix 5H). The means are lower for the final year than the third year. For the industrial side the mean is lowest for the third year but the standard deviation is quite high. The EngD students' satisfaction is lowest (mode = 3) for the first year students and the percentage of those who are 'satisfied' (4) increases by year of project (Table 13, Appendix 5H).

Tables 5.5 and 5.6 show the percentage of students, both CASE and EngD, who have encountered problems with project timescales and problems related to differences between the industrial and academic partners by year of project.

Table 5.5: Percentage of students who encountered problems with project timescales by year of project

Year of Project	*Encountered problems with project timescales?* Yes	No
1st	8.0%	92.0%
2nd	41.1%	58.9%
3rd	44.6%	55.4%
4th	65.2%	34.8%

Table 5.6: Percentage of students who encountered problems due to differences between the partners by year of project

Year of Project	*Differences between partners cause problems?* Yes	No	don't know
1st	14.3%	40.0%	45.7%
2nd	20.0%	63.6%	16.4%
3rd	27.0%	66.7%	6.3%
4th	36.4%	50.0%	13.6%

Interestingly 92% of first year students stated that they have not encountered problems with timescales and the percentage of students who have had problems increases by year of project. The percentage of students who have encountered problems when carrying out or reporting on their project due to differences between the industrial and academic partners also increases by year of project.

The influence of the enthusiasm of the supervisors on collaboration 'success' was investigated by comparing the 'success' means by how enthused the industrial and academic supervisors are in their project (Tables 14 & 15, Appendix 5H). The 'success' means are very low where the industrial supervisor is 'not at all enthused' and the more enthused the supervisor is the higher the means. The mean is very high for students whose industrial supervisor is 'very enthused'. A t-test for low versus high industrial enthusiasm using the neutral value on the Likert scale (3) as the 'cut-off point' (i.e. >=3 versus <3) indicates significant differences in all of the means (sig. = 0.00 for all 4 means). Looking at the 'success' means for the academic supervisor's enthusiasm, the means are lowest for the industrial and academic sides, not the student (personally) where the academic is 'not at all enthused'. The means are all highest where the academic supervisor is 'very enthused'. A t-test for low versus high academic enthusiasm (again using '3' as the cut-off point) indicates significant differences in all the means, particularly the academic side and overall 'success' means (sig. = 0.04; 0.04; 0.00 & 0.00 respectively). Tables 5.7 and 5.8 show the enthusiasm of the industrial and academic supervisors by year of project.

Table 5.7: Enthusiasm of industrial supervisor by year of project

Year of Project	*How enthusiastic is industrial supervisor about project?*				
	not at all enthused	*2*	*3*	*4*	*very enthused*
1st	0.0%	4.8%	12.7%	31.7%	50.8%
2nd	1.9%	8.4%	15.0%	26.2%	48.6%
3rd	5.3%	10.7%	16.0%	26.7%	41.2%
4th	4.8%	9.5%	14.3%	28.6%	42.9%

Table 5.8: Enthusiasm of academic supervisor by year of project

Year of Project	*How enthusiastic is academic supervisor about project?*				
	not at all enthused	*2*	*3*	*4*	*very enthused*
1st	0.0%	0.0%	4.2%	32.4%	63.4%
2nd	0.0%	1.8%	9.0%	32.4%	56.8%
3rd	2.3%	6.8%	9.1%	27.3%	54.5%
4th	0.0%	0.0%	33.3%	28.6%	38.1%

In Table 5.7 we can see higher percentages where the industrial supervisor is 'not at all enthused' for the 3rd and 4th years compared to the first two years, and lower percentages where the supervisor is 'very enthused' for the final years (3rd/4th) compared to the first two years. The percentage of cases where the academic supervisor is 'very enthused' also decreases by year of project (Table 5.8).

The influence of the supervisors' understanding of the project on perceived success was also explored by comparing the 'success' means by the extent that the supervisors were said to understand the work (Tables 16 & 17, Appendix 5H). The success means are all lowest where the industrial supervisor does not understand the work at all (very low for industrial side). The means all increase as the extent to which the industrial supervisor understands the work increases. The mean is very high where the industrial supervisor understands the work 'very well'. A t-test for low versus high industrial understanding using 3 as the cut-off point indicates significant differences in all of the means (sig. = 0.00 for all 4 means). The success means also increase as the extent that the academic supervisor understands the work increases, except for the industrial side where the mean is lowest where the academic's understands 'quite well' (4). A t-test for low versus high academic understanding, again using 3 as the cut-off point, indicates significant differences in all the means except for the industrial side (sig. = 0.03 (personally); 0.64 (industrial); 0.00 (academic) & 0.01 (overall)). Tables 5.9 and 5.10 show how the extent that the industrial and academic supervisors understand the work varies by year of project.

Table 5.9: Extent industrial supervisor understands work by year of project

Year of Project	*Extent industrial supervisor understands work*				
	not at all	*2*	*3*	*4*	*very well*
1st	1.6%	8.1%	16.1%	32.3%	41.9%
2nd	3.8%	10.4%	18.9%	32.1%	34.9%
3rd	4.5%	15.2%	19.7%	35.6%	25.0%
4th	0.0%	9.5%	33.3%	28.6%	28.6%

Table 5.10: Extent academic supervisor understands work by year of project

Year of Project	*Extent academic supervisor understands work*				
	not at all	*2*	*3*	*4*	*very well*
1st	0.0%	1.5%	7.6%	22.7%	68.2%
2nd	0.0%	3.6%	7.2%	27.9%	61.3%
3rd	0.0%	4.6%	9.9%	20.6%	64.9%
4th	0.0%	4.8%	38.1%	14.3%	42.9%

The extent that the industrial supervisors understand the work appears to decrease by year of project and for the academic supervisor the percentage that understands the work 'very well' is lowest for the 4th year.

iii) Size of company

In the survey of collaborative research facilitators, some of the respondents believed that there are bigger cultural differences between academic institutions and small companies than between academic institutions and large companies. There have also been indications in the literature that there is a significant culture gap between academics and businessmen in small companies, and that they have significant problems communicating with each other. In the questionnaire the students were asked to indicate the size of their industrial sponsors. Specific questions to be addressed by this element of the survey are:

- *Are collaborations with small companies less successful than those with large companies?*
- *What are the main problems encountered in projects with small companies?*
- *Is communication a big problem in collaborations with small companies?*

Table 5.11 shows the 'success' means by size of company; the means are lower for projects with small industrial organisations compared to those with large industrial organisations. The means for the student (personally) are similar for medium and large sized organisations but the other means (academic/industrial) are a little lower for medium sized organisations (compared to large). A t-test for small versus large industrial sponsor means indicates that the 'success' mean for the industrial side and the overall success mean are significantly different (sig. = 0.09 (personally); 0.01 (industrial); 0.05 (academic) & 0.01 (overall)).

Table 5.11: Comparing 'success' means by size of main industrial sponsor

Size industrial sponsor (main)		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Small	Mean	3.53	3.03	3.48	10.03
	N	40	40	40	40
	SD	1.037	1.025	.847	2.166
Medium	Mean	3.85	3.37	3.65	10.88
	N	48	48	48	48
	SD	1.091	1.064	.758	2.367
Large	Mean	3.81	3.43	3.77	11.02
	N	254	253	253	253
	SD	.995	.956	.876	2.333

[N = no. of cases; SD = standard deviation]

Table 5.12 shows the percentage of problems encountered by size of industrial sponsor. There are no significant differences by size of industrial sponsor in the percentages for poor compatibility, differences between partners and personnel changes. There have been no poor compatibility problems in projects with small companies. There were fewer project timescales problems in projects with large companies than in projects with small and medium companies. There is also an increase in the percentage of communication problems encountered between the students and supervisors by size of company. On the other hand, there is a decrease in the percentage of communication problems encountered between the partners by size of company. Therefore communication does appear to be a more significant problem between academics and small companies than it is between academics and large companies.

Table 5.12: Percentage of respondents encountering problems by size of industrial sponsor

'Problem' factor	Small	Medium	Large
Poor compatibility causes problems	-	2.2%	3.4%
Differences between partners cause problems	23.1%	20.4%	23.1%
Encountered project timescales problems	40%	46.8%	37.6%
Communication problems between student & supervisors	22.5%	27.1%	28%
Communication problems between partners	17.9%	10.2%	9.1%
Personnel change affected project	11.1%	8.2%	10.4%

5.3.3 Nature & effectiveness – 'successful' & 'unsuccessful' projects

In the survey of collaborative research facilitators, respondents were asked to describe 'good' and 'bad' examples of collaboration so that important collaboration success and breakdown factors could be identified. The 'success' factors identified were: generation of valuable outcomes, enthusiasm, good management (i.e. formal agreement in force), good communication (regular meetings), mutual interests, match of personalities and industry managing the relationship. The identified 'breakdown' factors were: personnel changes, poor communication, poor management (i.e. no agreement), company money problems, lack of contribution from one partner and personality clashes. In the questionnaire survey, the students' impressions of 'success' are evaluated through their responses to several questions including how they would measure the success of the collaboration personally, for the industrial side and for the academic side, and whether they felt that the relationship between the two parties has improved or worsened since they have started.

In this section the characteristics of 'successful' and 'unsuccessful' projects are explored to identify the factors contributing to each case. A non-reflexive method was used to select the cases (projects) that qualify under 'successful' and 'unsuccessful' so that there are the same numbers of cases (30) under each category as follows:

- *'Successful' projects* - cases where the 'overall success' measure is at the maximum score of 15 (overall success = sum of 'success' scores for personally, for the industrial side & for the academic side).
- *'Unsuccessful' projects* – cases where each of the three 'success' measures equals to 1 or 2, or where the relationship between the two parties (industrial & academic) has 'worsened'.

It is acknowledged that this method was probably not the most appropriate way of selecting 'unsuccessful' and 'successful' projects. Alternative methods of selecting 'unsuccessful' projects (e.g. cases where the overall success measure is at the minimum score of 3) do not provide a sufficient number of 'unsuccessful' cases to examine in comparison to 'successful' projects.

The specific questions to be addressed by this aspect of the survey, and that will be answered in the next two sub-sections, are:

- *What are the characteristics of the most successful collaborations?*
- *What are the characteristics of the least successful collaborations?*

i) Characteristics of 'successful' projects

This section explores the 30 cases where the 'overall success' measure is at the maximum score of 15. In order to find out which factors made these projects 'highly' successful (i.e. what combination of ('success') factors helped make these projects more successful) a range of variables in the database will need to be looked at. The database was 'filtered' so that only the data for 'successful' projects are shown (i.e. 'select if' overall success = 15 (sum of the 3 success measures)).

Of the 30 'successful' cases, half involved third year students, nine involved second year students and six involved first year students. Just over three quarters of these cases involved large industrial sponsors, five cases involved medium sized companies and two cases involved small companies. In 70% of the cases, the student spends less than 25% of their time working at the industrial institution. Looking at some of the variables related to the project supervisors (see Table 5.13), large proportions of the 'successful' cases involved partners who have worked together before, supervisors who both have a very good understanding of the work and supervisors who have very high enthusiasm for the project. None of the 30 cases involved 'poorly compatible' (<3) supervisor backgrounds, with just over 60% involving supervisors with 'very compatible' backgrounds. For over three quarters of the cases, there have not been any problems due to differences between the partners.

Table 5.13: Variables related to supervisors for 'successful' projects

Variable description	Percentage (category) or Mode (likert scale)
Partners worked together before?	Yes = 83.3%; No = 13.3%; Don't know = 3.3%
Extent supervisors understand work	Industrial supervisor = 5 'very well' (73.3%) Academic supervisor = 5 'very well' (93.3%)
Enthusiasm of supervisors	Industrial supervisor = 5 'very enthused (80%) Academic supervisor = 5 'very enthused (83.3%)
Compatibility of supervisors' disciplinary backgrounds	5 'very compatible' (63.3%) (none rated < 3)
Differences between partners cause problems?	No = 76.7%; Yes = 13.3%; Don't know = 6.7%

Examining the variables related to project management (see Table 5.14), the 'restrictiveness' of most of the 'successful' cases is 'slightly' restricted (mode = 2) and just over half of the projects have a Gantt chart or list of deliverables. Only three cases encountered problems with project timescales and three cases had personnel changes in the coordination group. For 70% of the 'successful' projects, the academic partner provides most leadership and for just over half of the cases, both partners manage the relationship. Only a quarter of these projects have a collaboration agreement, but most students were not sure if there is one in force. In 60% of the cases, the students have been asked to sign a confidentiality agreement.

Table 5.14: Variables related to project management for 'successful' projects

Variable description	Percentage (category) or Mode (likert scale)
'Restrictiveness' of project management/supervision	Mode = 2 (36.7%) (1 'not at all' = 33.3%)
Gantt chart or list of deliverables for project?	Yes = 53.3%; No = 26.7%; Not sure = 20%
Encountered problems with project timescales?	No = 73.3%; Yes = 10%
Which partner provides most leadership?	Academic = 70%; Equal = 20%; Industrial = 10%
Who coordinates/manages relationship?	Both = 56.7%; Academic = 33.3 %; Industrial = 6.7%
Personnel changes in coordination group?	No = 80%; Yes = 10%
Collaboration agreement in force?	Not sure = 56.7%; Yes = 26.7%; No = 16.7%
Asked to sign confidentiality agreement?	Yes = 60%; No = 40%

For those factors related to communication (see Table 5.15), over half of the 'successful' cases have quarterly meetings, but interestingly a quarter of the cases meet just once a year. For 90% of the cases, there have not been any communication problems, either between the students and their supervisors or between the industrial and academic partners. The quality of communication (which indirectly indicates relationship building) has 'improved' over time for 90% of the students involved in 'successful' projects.

Table 5.15: Variables related to communication for 'successful' projects

Variable	Percentage (category) or Mode (likert scale)
How frequently joint project meetings held?	< once a year = 6.7%; Once a year = 26.7%; Quarterly = 53.3%; once a month = 6.7%; > once a month = 6.7%
Any communication problems with supervisors?	No = 90%; Yes = 10%
Communication problems between partners?	No = 90%; Yes = 3.3%
Quality of communication over time	Improved = 90%; not sure = 10%

The means which describe the extent to which the 'successful' projects are characterised by good management (4.43), by good communication (4.45) and by mutual interest/need (4.60) are quite high, in particular for the latter.

Looking at the comments provided by 8 of the 30 'successful' cases; two comments related to the supervisors having collaborated together before and only a few cases commented on 'minor' problems that they have encountered which include confidentiality and problems setting up meetings where multiple partners are involved. Some of the suggestions to help improve collaborative research provided by the 'successful' cases include good communication of expectations, agreement at the outset, developing mutual understanding, regular meetings, promoting trust and flexibility.

ii) *Characteristics of 'unsuccessful' projects*

This section explores the 30 cases where the three success measures ('personally', 'for the industrial side' & 'for the academic side') were rated 1 or 2, or where the relationship between the two parties has 'worsened'. As in the previous section, most of the variables need to be looked at in order to find out which factors might contribute to these projects being 'less successful' (i.e. what combination of factors made these projects less successful). As in the example of the 'successful' cases, the database was 'filtered' so that only the data for 'unsuccessful' projects are shown.

Of the 30 cases, two were fourth year students, just over half were third year students, four were second year students, four were first year students, and two were part-time students (1 = unknown year). Just over 60% of these cases involved large industrial sponsors, five cases involved medium sized companies and five cases involved small companies. As for the 'successful' cases, in most (70%) of the 'unsuccessful' cases, the student spends less than 25% of their time working at the industrial institution. Looking at some of the variables related to the supervisors (see Table 5.16), in over half of the 'unsuccessful' cases the partners have not worked together before. The mode is still 5 (but lower % cases) for the extent that the academic supervisor understands the work but for the industrial supervisor the mode is 2 ('little understanding') for just over 40% of the projects. The academic supervisor's enthusiasm is still quite high but the mode for the industrial supervisor's enthusiasm is 1 ('not enthused at all'). The mode for the compatibility of the supervisors' backgrounds is 3 and only 2 cases involved 'very compatible' supervisor backgrounds. Sixty percent of the 'unsuccessful' projects have encountered problems due to differences between the partners.

Table 5.16 Variables related to supervisors for 'unsuccessful' projects

Variable description	Percentage (category) or Mode (likert scale)
Partners worked together before?	Yes = 36.7%; No = 53.3%; don't know = 10%
Extent supervisors understand work	Industrial supervisor - 2 (43.3%) Academic supervisor -5 (43.3%)
Enthusiasm of supervisors	Industrial supervisor - 1 (30%) Academic supervisor - 4 (40%)
Compatibility of supervisors' disciplinary backgrounds	3 'neutral' (33.3%)
Differences between partners cause problems?	Yes = 60%; No = 23.3%; don't know = 13.3%

Exploring the variables related to project management (Table 5.17), the mode is 1 for responses on project 'restrictiveness', although half of the projects do have a Gantt chart or list of deliverables. In 60% of the 'unsuccessful' cases the students encountered problems with timescales and in two thirds of the cases the project objectives or methods have changed (compared to 47% for 'successful' projects).

Table 5.17: Variables related to project management for 'unsuccessful' projects

Variable	Percentage (category) or Mode (likert scale)
'Restrictiveness' of project management	Mode = 1 (40%)
Gantt chart or list of deliverables for project?	No = 50%; Yes = 40%; not sure = 10%
Encountered problems with project timescales?	Yes = 60%; No = 26.7%
Changed project objectives / research methods?	Yes = 66.7%; No = 30%
Which partner provides most leadership?	Academic = 76.7%; Industrial = 13.3%; Equal = 10%
Who coordinates/manages relationship?	Academic = 70%; Both = 23.3%; Industrial = 6.7%
Personnel changes in coordination group?	No = 63.3%; Yes = 33.3%
Collaboration agreement in force?	Not sure = 40%; Yes = 33.3%; No = 26.7%
Asked to sign confidentiality agreement?	Yes = 40%; No = 36.7%; not sure = 20%

A third of the projects have had personnel changes in the coordination group. For just over three quarters of the projects, the academic partner provides most leadership and in 70% of the cases the academic manages the relationship. Less than a quarter of the projects are managed by both partners. A third of the 'unsuccessful' cases have a collaboration agreement, but again many students were not sure if there is one in force. In 40% of the projects, the student was asked to sign a confidentiality agreement.

Related to communication, 40% of the 'unsuccessful' cases have meetings just once a year and for five cases the meetings take place less than once a year (Table 5.18). For two thirds of the cases, the student has had communication problems with their supervisors and in 40 % of the projects, there have been communication problems between the partners. For just over a third of the cases, the quality of communication has worsened over time.

The means which describe the extent to which the 'unsuccessful' projects are characterised by good management (2.57), by good communication (2.73) and by mutual interest/need (2.77) are quite low, in particular for good management.

Table 5.18: Variables related to communication for 'unsuccessful' projects

How frequently joint project meetings held?	< once a year = 16.7%; Once a year = 40%; Quarterly = 36.7%; once a month = 6.7%
Any communication problems with supervisors?	No = 26.7%; Yes = 66.7%; not sure = 3.3%
Communication problems between partners?	No = 36.7%; Yes = 40%; not sure 23.3%
Quality of communication over time	Improved = 23.3%; Worsened = 36.7%; not sure = 36.7%
How satisfied with project's progress?	4 (33.3%)

Looking at the comments provided by students linked with the 'unsuccessful' cases, it is evident that in many cases there is a combination of several 'negative' factors. The most significant factor that emerges from the comments made by just over a third of the 'unsuccessful' cases is the different expectations or views of the partners. Other important factors mentioned by respondents include poor communication, problems with the industrial supervisor (lack of interest), different reporting requirements and industrial partner personnel changes.

5.3.4 Project management

In the survey of collaborative research facilitators, the respondents gave a variety of opinions on how formal project management arrangements should be in industry-academia collaborations but many emphasised the importance of having a collaboration agreement in force. Some interviewees stated that there should be more structure for multi-partner collaborations but with some flexibility to allow for changes (i.e. have an adaptive or responsive structure). A few respondents claimed that it is best not to leave the management to academics. The specific questions to be addressed by this element of the survey are:

- *Are collaborative projects with a restrictive project management structure more successful than those with no/little structure?*
- *Are projects considered more successful if there is a collaboration agreement in place?*
- *Are projects managed by industry considered more successful?*

In the questionnaire the students were asked to rate how 'restrictive' their project management or supervision is, i.e. how inflexible their project structure is in terms of objectives, procedures, timescales, etc., on a scale of 1 to 5 where 1 is 'not at all restrictive' and 5 is 'very restrictive'. Table 5.19 compares the 'success' means by project 'restrictiveness'. The 'success' means are lowest for projects which have a 'very restrictive' structure but there were only three projects within this category. The success means for the student and the academic partner are highest for projects judged to have a restrictiveness of 2 (flexible with a little bit of structure?). For the industrial side, the success mean is highest where 'restrictiveness' is judged at 4. A t-test comparing the means using 3 as the 'cut-off point' (i.e. >=3 'high restrictiveness' versus <3 'low restrictiveness') indicates that only the student's (personally) means are significantly different as a function of project management style (sig. = 0.00 (student); 0.30 (industrial); 0.47 (academic) & 0.05 (overall)).

Table 5.19: Comparing the 'success' means by project management 'restrictiveness'

How restrictive is project management?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
1 'not at all restrictive'	Mean	3.89	3.33	3.68	10.90
	N	91	91	91	91
	SD	1.120	1.096	1.031	2.684
2	Mean	3.94	3.52	3.81	11.27
	N	116	116	116	116
	SD	.907	.918	.757	2.070
3	Mean	3.60	3.25	3.68	10.53
	N	88	87	87	87
	SD	.977	.943	.770	2.199
4	Mean	3.57	3.57	3.77	10.90
	N	30	30	30	30
	SD	1.165	1.006	.817	2.398
5 'very restrictive'	Mean	3.33	2.67	3.00	9.00
	N	3	3	3	3
	SD	.577	1.528	1.000	2.646

[N = no. of cases; SD = standard deviation]

Looking at the means which relate to 'the extent to which the project is characterised by good management' by project management 'restrictiveness' (Table 18, Appendix 5H) shows that the mean is highest where the project management restrictiveness is 3, suggesting that some flexibility and some structure is characteristic of good management.

The 'success' means for projects which have a Gantt chart or list of deliverables or milestones were compared with the means for projects which do not have one (see Table 5.20). Here the success means (particularly for the industrial side) are lower for projects which do not have a Gantt chart. A t-test shows significant differences in all the means except for the student (sig. = 0.12 (personally); 0.00 (industrial); 0.30 (academic) & 0.00 (overall).

Table 5.20: Comparing the 'success' means by yes / no Gantt chart

Gantt chart or list of deliverables/milestones for project?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.87	3.58	3.81	11.26
	N	144	144	144	144
	SD	1.003	.965	.885	2.374
no	Mean	3.68	3.15	3.57	10.40
	N	128	127	127	127
	SD	1.042	1.001	.904	2.358

[N = no. of cases; SD = standard deviation]

Table 5.21 compares the means for projects which have a collaboration agreement in force and for projects which do not have one. The means are slightly higher where there is a collaboration agreement in force. A t-test indicates that only the means for the academic side are significantly different (sig. = 0.32 (personally); 0.50 (industrial); 0.04 (academic) & 0.14 (overall).

Table 5.21: Comparing the 'success' means for projects with a collaboration agreement in force versus those which do not have one

Collaboration agreement in force?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.84	3.39	3.78	11.01
	N	124	124	124	124
	SD	.991	1.002	.822	2.221
no	Mean	3.67	3.29	3.51	10.46
	N	63	63	63	63
	SD	1.178	.923	.965	2.614

[N = no. of cases; SD = standard deviation]

To find out whether successful projects are characterised by one type of partner playing a dominant role in the coordination or management of the relationship, the 'success' means are compared by who manages the collaboration (see Table 5.22). The 'success' means are highest where both partners coordinate or manage the relationship. Comparing industry versus academic management, all the 'success' means except for those relating to the industrial side are higher when the academic manages the relationship. Interestingly the success mean is low for the academic side if industry manages the relationship and vice versa (low for the industrial side if the academic manages the relationship). A t-test comparing industry versus academic management indicates no significant differences in the means (sig. = 0.79; 0.15; 0.10 & 0.73 respectively).

Comparing the means for the extent to which the project is characterised by good management by who manages the relationship (Table 19, Appendix 5H) shows that the mean is lowest where the industrial partner manages the relationship and highest where both partners manage the project.

Table 5.22: Comparing the 'success' means by who coordinates/manages the relationship

Who coordinates/manages relationship?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Industrial	Mean	3.67	3.48	3.24	10.38
	N	21	21	21	21
	SD	1.155	1.123	1.261	2.747
Academic	Mean	3.73	3.13	3.72	10.57
	N	168	167	167	167
	SD	1.047	1.037	.798	2.348
Both	Mean	3.86	3.65	3.79	11.30
	N	146	146	146	146
	SD	.961	.835	.838	2.214

[N = no. of cases; SD = standard deviation]

There were three comments from EngD students stating that they coordinate or manage the relationship and chair the meetings themselves (an option not given on the questionnaire so there may have been others). For two of these students, the extent the project is characterised by good management is 4 (of 5) and for one student it is 2 (of 5). The overall success scores of these projects are however quite low: only 6 (of 15) for one student, and 9 and 10 (of 15) for the other two.

The following sub-section explores the influence of prior collaboration experience, an issue that came up both in the literature and the survey of collaborative research facilitators and that is believed to facilitate the management of collaborative research.

i) Prior collaboration experience

In the interviews with the collaborative research facilitators, it was suggested that joint projects with no prior history of collaboration between the partners encounter more difficulties, especially in setting up agreements. In the questionnaire students were asked if the partners had worked together before their project. Specific questions to be addressed by this aspect of the survey are:

- *Are collaborative projects more successful if the partners have worked together before or have collaboration experience?*

- *Do partners with a history of collaboration have fewer problems with the collaboration agreement?*

To find out if the projects are more 'successful' if the partners have collaborated before, the 'success' means are compared for projects where they have worked together before and for those where they have not (Table 5.23). The means are higher for projects where the two partners have worked together before and a t-test confirms that the means are significantly different (sig. = 0.00 for all 4 means).

Table 5.23: Comparing the 'success' means for projects where the partners have worked together before versus those where they have not

Partners worked together before project?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.92	3.50	3.82	11.25
	N	202	202	202	202
	SD	.922	.921	.845	2.241
no	Mean	3.57	3.20	3.53	10.30
	N	111	111	111	111
	SD	1.084	1.043	.872	2.376

[N = no. of cases; SD = standard deviation]

There were also several comments from the students emphasising the benefits of having supervisors that have collaborated before; these are shown in Table 20, in Appendix 5H. The following cross-tabulation (Table 5.24) illustrates whether there are fewer collaboration agreement problems in projects where the partners have worked together before compared to those where the partners have not collaborated before.

Table 5.24: Percentage encountered problems with collaboration agreement by whether the partners have worked together before or not

Partners worked together before project?	*Collaboration agreement - encountered any problems?*		
	yes	*no*	*not sure*
yes	5.9%	86.8%	7.4%
No	4.2%	89.6%	6.3%

The percentage of projects which encountered collaboration agreement problems is slightly higher where the two partners have worked together before, not lower.

5.3.5 Communication

The survey of collaborative research facilitators highlighted the importance of face-to-face communication and regular meetings. Ineffective communication is shown in the literature review to be a common barrier in industry-academia collaboration. The primary results revealed that 27% of the students encountered communication problems with their supervisors and that there were communication problems between the industrial and academic partners in 11% of the cases. Communication problems were also a frequently mentioned topic in the students' comments on other problems which they have encountered, mainly concerning a lack of or infrequent communication. In the questionnaire the students were asked how important the three communication modes: email, phone and face-to-face, are for communicating with their supervisors. They were also asked how frequently they have joint project meetings (with both industrial and academic partners). The specific questions to be addressed by this element of the survey are:

- *How important are the different modes of communication (i.e. face-to-face, email & phone) for the students for communicating with their supervisors?*
- *Are projects with frequent meetings, i.e. quarterly or more often, more successful than those which have meetings less frequently?*
- *Do communication problems significantly influence project success?*

The primary results showed that most students rated face-to-face as more important than the other communication methods (mean score = 4.7, see Appendix 5E) for communicating with their academic supervisor. For communicating with their industrial supervisor however, email had a higher score (mean = 4.1) than face-to-face. Table 5.25 shows the 'success' means by how frequently project meetings take place.

Table 5.25: Comparing the 'success' means by meeting frequency

How frequently joint project meetings held?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Less than once a year	Mean	3.22	2.38	3.31	8.88
	N	27	26	26	26
	SD	1.396	1.134	1.123	3.103
Once a year	Mean	3.76	3.24	3.77	10.77
	N	97	97	97	97
	SD	1.018	1.078	.872	2.378
Quarterly	Mean	3.87	3.52	3.74	11.12
	N	187	187	187	187
	SD	.977	.857	.810	2.135
Once a month	Mean	3.71	3.58	3.67	10.96
	N	24	24	24	24
	SD	.859	.881	.816	1.989
More frequently than once a month	Mean	3.78	3.89	3.78	11.44
	N	9	9	9	9
	SD	.972	.782	.972	2.698

[N = no. of cases; SD = standard deviation]

The 'success' means are lowest in projects where meetings are held less than once a year. All the means except for the student (personally) are highest where the meetings are held more frequently than once a month. For the student the mean is highest where the meetings are held quarterly. For the industrial side the means increase by meeting frequency. A t-test comparing the means for low versus high meeting frequency (using 3 as the cut-off point, i.e. >=3 versus <3) indicates significant differences in the means for the industrial side and also the overall 'success' means (sig. = 0.10 (personally); 0.00 (industrial); 0.56 (academic); 0.01 (overall)).

Table 5.26 shows the 'success' means for projects where the student encountered communication problems with their supervisors and for those which have not had such problems. All the 'success' means are lower for projects where the students encountered communication problems with their supervisors. A t-test indicates that the means are significantly different (sig. = 0.00 for all 4 means).

Table 5.26: Comparing the 'success' means by if the student has encountered communication problems with their supervisors or not

Encountered any communication problems with supervisors?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.34	2.91	3.34	9.60
	N	94	94	94	94
	SD	1.223	1.104	.862	2.494
no	Mean	3.97	3.54	3.88	11.38
	N	243	242	242	242
	SD	.881	.888	.784	2.091

[N = no. of cases; SD = standard deviation)

Table 5.27 shows the 'success' means for projects which have had communication problems between the partners. For projects where there have been communication problems between the partners, the 'success' means are lower. Again a t-test indicates that the means are all significantly different (sig. = 0.00 for all 4 means).

Table 5.27: Comparing the 'success' means by if there have been communication problems between the partners or not

Communication problems between partners?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.11	2.54	3.22	8.86
	N	37	37	37	37
	SD	1.220	1.260	.976	2.710
no	Mean	3.97	3.57	3.87	11.41
	N	223	223	223	223
	SD	.925	.902	.833	2.177

[N = no. of cases; SD = standard deviation]

5.3.6 Best practice suggestions

In the interview survey of collaborative research facilitators, the participants were asked what they would put in a document providing best practice guidelines for industry-academia collaboration. Some of the suggestions that were put forward included promoting mutual understanding, regular communication, clarity of needs or expectations, good management and flexibility. The students were also asked to put forward any suggestions they have that could help collaborative research. The specific questions to be addressed by this element of the survey are:

- *Which best practice advice provided by the collaborative research facilitators was confirmed by responses from the students?*
- *What additional advice on best practice has been provided by the students?*

Like the collaborative research facilitators the students provide quite a wide variety of suggestions. The following list shows the five most frequently mentioned topics in their suggestions: *(in descending order of frequency (count))*

- Planning or agreement (at outset; particularly for timescales, IPR & changes) (21);
- Communication (more contact, keep all parties informed, regular meetings) (15);
- Industrial placement (better planning, longer placements, placement at start of project, etc.) (11)
- Clarity on roles of participants (including student's) and expectations (9);
- More industrial input or leadership (7)

There are some similarities in the topics frequently mentioned by the students and by the collaborative research facilitators including good management (better planning/agreement at outset), regular communication and clarity of expectations. Other similar topics that have been suggested by both response groups include promoting mutual understanding and having flexibility in the project management structure. Some good practice suggestions made by the students were not highlighted in the interview survey including better planning of industrial placements and ensuring that industry understands what the student's role involves. There was one interesting comment from one student stating that research contract departments within universities should be trained to understand the needs of industry and that they should read the guidelines on industry-academia collaborations laid down in a research council handbook.

5.3.7 Sectoral variations

In the survey of collaborative research facilitators, many interviewees emphasised that there are variations in industry-academia collaboration between different industrial sectors. For example, several respondents mentioned that the pharmaceutical industry are used to long-term research and have good links with universities; also the people working in this sector have more compatible disciplinary backgrounds with those of academics. This is not the case for the manufacturing sector. Also there are fewer collaborations which involve social sciences. As we saw in Chapter 2, science-based firms are well prepared to communicate with universities as they know their codes and cultures, whereas academics and craft-based traditional firms (e.g. water utilities) have great difficulties working together because their cultures are so far apart. The specific questions to be addressed by this element of the survey are:

- *Are there variations in project success (or problems) across different sectors?*
- *Are the success measures higher (less problems?) for projects with pharmaceutical companies than for projects with water companies?*

The term 'different sectors' is interpreted as corresponding to the five different research councils that fund EngD and CASE projects. Therefore the 'success' means are compared by research council (Table 5.28).

The NERC funded projects (natural environment) have the highest 'success' means compared to those funded by the other Research Councils. The EPSRC funded projects (engineering & physical sciences, including the EngD projects) have the lowest 'personal', 'academic' and 'overall' 'success' means. The success mean for the industrial side in engineering is however higher compared to those in BBSRC (biotechnology & biological sciences) and ESRC (economic & social research) funded projects.

Table 5.28: Comparing the 'success' means by sector (Research Council)

Research Council		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
NERC	Mean	3.95	3.64	3.89	11.47
	N	73	72	72	72
	SD	.864	.924	.848	2.214
PPARC	Mean	3.81	3.56	3.69	11.06
	N	16	16	16	16
	SD	.911	.892	.793	2.144
BBSRC	Mean	3.77	3.20	3.84	10.80
	N	86	86	86	86
	SD	1.155	1.038	.810	2.477
ESRC	Mean	3.84	3.20	3.67	10.70
	N	61	61	61	61
	SD	1.067	.980	.724	2.147
EPSRC	Mean	3.62	3.39	3.52	10.54
	N	109	109	109	109
	SD	1.007	.991	.958	2.444

[N = no. of cases; SD = standard deviation]

Table 5.29 shows the percentage of projects which have encountered problems in relation to poor compatibility, differences between the partners, timescales and communication within each sector.

Table 5.29: Percentage of projects which have encountered problems by sector

'Problem' factor	EPSRC	ESRC	NERC	PPARC	BBSRC
'Poorly' compatible supervisor backgrounds causes problems	3.1%	5.1%	2.9%	-	2.5%
Differences between partners cause problems	26.4%	27.1%	9.7%	26.7%	24.7%
Encountered project timescales problems	43.4%	50%	25.8%	26.7%	38.5%
Communication problems between student & supervisors	29.4%	37.7%	14.9%	33.3%	26.7%
Communication problems between partners	8.1%	16.4%	8.3%	6.3%	12.9%

ESRC has the highest percentage for all the 'problem' factors listed compared to the other sectors. On the other hand, NERC has very small percentages for problems due to differences between the partners and also for communication problems between the student and their supervisors compared to the other sectors.

The following cross-tabulation (Table 5.30) shows the percentage of projects which involve partners who have worked together before for each research council. It roughly indicates how 'experienced' each sector is in collaboration. For just over half of the ESRC funded projects the partners have not worked before, whereas this was the case for only 16% of NERC funded projects.

Table 5.30: Percentage of projects which involve partners who have worked together before by Research Council

Research Council	*Partners worked together before project?*		
	Yes	*No*	*don't know*
EPSRC	63.1%	29.7%	7.2%
ESRC	42.6%	50.8%	6.6%
NERC	71.6%	16.2%	12.2%
PPARC	75.0%	25.0%	
BBSRC	50.0%	37.2%	12.8%

Looking at some of the students' comments related to the field that they work in; one ESRC student believes that collaboration '*works better in non-social science subjects*'. One student working in the marine ecology and fisheries field (NERC) stated that his project is '*more of an example of academia-academia relationship*', as 'industry' in this field do not differ much from research in the academic field. Another NERC student also mentioned that because his industrial partner (government research centre) is also '*quite academic based*', many of the potential problems do not apply to his project.

The 'success' means by size of company within each sector (research council) were also explored (Table 21, Appendix 5H). Here the 'success' means for the student, the academic side and the overall success mean are lowest in projects with small engineering firms. The 'success' means for the industrial side are lower in projects with small companies within social sciences (ESRC) and biotechnology (BBSRC). Projects with large companies within the physics (PPARC), environmental science (NERC) and social science (ESRC) sectors are more successful, whereas within the engineering (EPSRC) and biotechnology (BBSRC) sectors, collaborations with medium sized companies have higher success.

In the database, 11 collaborative projects involving water utilities and 45 projects involving well known pharmaceutical companies were identified. Comparisons were made of the 'success' means of these projects to find out if collaborations with pharmaceutical companies are more successful than those with water companies (see Table 5.31). The 'success' means are very similar for the industrial and academic sides. For the student, the mean is slightly higher for those working with pharmaceutical companies but a t-test indicates that the means are not significantly different (sig. = 0.73).

Table 5.31: Comparing the 'success' means for projects with water & pharmaceutical companies

Sector		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Water	Mean	3.82	3.36	3.91	11.09
	N	11	11	11	11
	SD	.874	1.120	.831	2.625
Pharma-ceutical	Mean	3.93	3.38	3.96	11.27
	N	45	45	45	45
	SD	1.031	1.007	.767	2.260

[N = no. of cases; SD = standard deviation]

Tables 5.32 and 5.33 show the percentage of projects that have encountered problems due to differences between the industrial and academic partners, to project timescales and to communication for collaborative projects with water and pharmaceutical companies.

Table 5.32: Percentage encountered problems due to differences between partners & to timescales: water v. pharmaceutical companies

Sector	*Differences between partners cause problems?*			*Encountered problems with project timescales?*	
	Yes	*no*	*don't know*	*yes*	no
Water	27.3%	72.7%		72.7%	27.3%
Pharma-ceutical	17.8%	68.9%	13.3%	35.9%	64.1%

Table 5.33: Percentage encountered communication problems: water v pharmaceutical companies

Sector	*Encountered any communication problems with supervisors?*		*Communication problems between partners?*		
	Yes	*no*	*yes*	*no*	*not sure*
Water	27.3%	72.7%	9.1%	72.7%	18.2%
Pharma-ceutical	24.4%	75.6%	4.4%	77.8%	17.8%

Table 5.32 shows that the percentages for problems related to differences between the partners and project timescales are higher for projects with water companies. In nearly three quarters of the projects with water utilities the students encountered problems with timescales. The percentages are similar for communication problems between the student and their supervisors, but for communication problems between the partners the percentage is slightly higher for projects with water companies (Table 5.33).

5.3.8 Issues related to students

This section explores those aspects of the collaboration process directly related to the students including: their role in the collaborative project (sub-section i), correlations between their industrial knowledge or experience and the perceived success of their projects (sub-section ii) and the relationship between student age and perceptions of collaboration success (sub-section iii).

i) Students' role

In the literature review there have been indications that in industry-academia collaborative projects which involve students, many obstacles arise from the need to protect the students' academic interests. Also, because of industry's lack of understanding of the student's role, there is a risk of students being treated as "employees" and of their time being misused by industry. There is also evidence in the literature that the publishing behaviour of students and academic supervisors who are involved in collaboration can be altered due to confidentiality issues. Specific questions to be addressed by this aspect of the survey are:

- *Have any students encountered problems in relation to industry not understanding their role?*
- *Have there been occasions when student time has been misused by industry?*
- *Is confidentiality a big problem? Has it affected students' publishing behaviour?*
- *Are projects where students have signed a confidentiality agreement more successful?*

There have been several comments from the students related to industry not being fully aware of their role; some of these comments are shown in Table 5.33. Some suggestions have also been provided by students related to making industry more aware of their role – these are shown in Table 22 in Appendix 5H. From these comments it can be seen that some students have been treated as "employees" and have been asked to do extra work that is not related to their projects. Another issue that can be seen in their comments is the differences in anticipated timescales because the industrial partners do not understand fully the nature or length of CASE or EngD research projects.

Table 5.34: Comments from students on their role in the project

Student ID	Comment
JOLL	Industrial supervisor I think sometimes forgets that I am a student and not an employee as he keeps expecting me to start particular work at set time to save him being hassled from others overseeing the project funding, without really giving me much time to work on them especially on learning the basics for my literature review. Sometimes it seems that my supervisors running the project and not me.
HBEC	Differing expectations due to industrial partners not fully understanding nature/length/depth of a PhD - thus expecting output very quickly, and requiring extra work/input from me which interfered with PhD work - but this was resolved with help from academic supervisor
DCAR	If the company has not had an EngD student before, there is not so much guidance from the University as I feel there should be.
RCUR	Industrial supervisors... are poorly briefed from the outset and so tend not to be aware of why I am away on courses, the structure of the EngD etc - they should be more aware of the researchers needs, requirements academically etc.
SKIR	There is also the question of the company expecting the student to do a significant amount of work for them which is not related to the project and this often interferes with the said project.

Looking at issues related to confidentiality, in the earlier section on barriers and problems in collaboration (Section 5.3.2), it was revealed that 'publication or confidentiality' was the third most frequently mentioned topic in the students' descriptions of problems related to differences between the two partners. Some of the students' comments related to publication or confidentiality issues are shown in Table 23 in Appendix 5H. These comments suggest that students' publishing behaviour can be altered by concerns over confidentiality - either they are prevented from publishing some of their work or there is a delay in publication because it needs to be approved by the industrial partner ('clearing process'). One student stated that he is unable to show even his academic supervisor some of the results or data he produces for the industrial partner.

Table 5.35 shows the 'success' means for projects where the student was asked to sign a confidentiality agreement. The 'success' means are slightly higher for projects where the student was asked to sign a confidentiality agreement but a t-test indicates that the means are not significantly different (sig. = 0.76; 0.22; 0.29 & 0.30 respectively). The 'success' means for projects where the student was asked to sign the collaboration agreement were also explored (Table 24, Appendix 5H). The 'success' means are only slightly higher for the student and the academic side in projects where the student was asked to sign the collaboration agreement. For the industrial side however the mean is lower. Again a t-test indicates that the means are not significantly different (sig. = 0.74; 0.47; 0.77 & 0.94).

Table 5.35: Comparing the 'success' means for projects where the student was asked to sign confidentiality agreement versus those where they were not

Asked to sign confidentiality agreement?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
yes	Mean	3.85	3.48	3.77	**11.09**
	N	162	162	162	162
	SD	.956	.986	.895	2.312
no	Mean	3.81	3.34	3.66	10.81
	N	148	147	147	147
	SD	1.052	.947	.848	2.356

[N = no. of cases; SD = standard deviation]

There were comments from two students who do not have a collaboration agreement in force for their projects and as a consequence are having problems with IPR and confidentiality or publication. These comments are shown below:

> *'Currently issues are being discussed with reference to IPR and confidentiality due to the lack of any formal agreement being drawn up at the beginning of the project.' (LYOU)*
>
> *'There is no collaboration agreement. This is a long and sorry saga of incompetence which depresses me if I allow myself to think about it. Because my work is commercially sensitive there are issues with publication and I will only publish 1 paper out of potential 3. An EngD is aimed at Industry to prepare students for early advancement into senior roles, and publication may raise serious confidentiality issues. IP ownership is also a concern.' (TKIR)*

Another student mentioned that *'it would be very useful to involve the student as much as possible in outlining the project and to set clear guidelines and objectives at least for the first year to provide focus and increase student confidence in the project'* (JASK).

ii) Industrial experience

As mentioned earlier in the section on industrial motivations (5.3.1, sub-section i), the primary questionnaire results (Appendix 5D) showed higher 'uncertain' percentages in the students' responses for questions related to the industrial partner. Also the next section which compares the responses from CASE students with those from EngD students demonstrates that CASE students seem more 'uncertain' about most of the industrial motivations compared to EngD students, probably because they spend less time with their industrial partner. Therefore in this section, the 'uncertain' percentages (for variables related to industry) as well as the 'success' means are compared by the time students spend with their industrial sponsors. The specific question to be addressed by this element of the survey is:

- *Does spending more time located with the industrial partner make collaboration more successful?*

Table 5.36 shows the 'uncertain' percentages for variables related to industry for students who spend 25% or less of their time located with the industrial partner and for students who spend 50% or more of their time at industry. It also shows the uncertain percentages for first year versus third year students. The 'uncertain' percentages are higher for students who spend less time at industry (25% or less) and for the first year students, which suggests that students gain more understanding of industry by spending a greater proportion of their time with them and also over the duration of their projects.

Table 5.36: 'Uncertain' responses by time spent with industrial partner & by year of project

Variable (related to industry)	*Time spend at industry*		*Year of project*	
	25% or less	*50% or more*	*1st year*	*3rd year*
Industrial motivations:				
'to extend knowledge base'	4.8%	3.9%	5.7%	3.8%
'to access university facilities'	11.4%	2%	18.6%	7.6%
'to access students'	17.2%	9.8%	24.3%	13.6%
'to boost sales/income'	19.3%	11.8%	30%	11.4%
'to avoid in-house investment'	23.4%	18%	38.6%	14.5%
'for immediate problem solving'	13.8%	2%	24.3%	7.6%
'to raise profile within society'	16.9%	9.8%	25.7%	11.4%
'to obtain prestige in market'	22.4%	15.7%	34.3%	13.6%
Extent industrial supervisor understands work	3.8%	2%	11.4%	-
How enthusiastic is industrial supervisor about project?	4.5%	-	10%	0.8%

The 'success' means as a function of the proportion of time students spend with industry are also compared – see Table 5.37. Ignoring the means for '75%' which involves only one case, the 'success' means are all highest where the student spends 50% of their time at industry. Interestingly the success mean for the academic side is lowest where the student spends more than 75% of their time at industry and the mean for the industrial side is lowest where the student spends less than 25% of their time at industry. A t-test using 50% as the cut-off point (i.e. <50% versus >=50% of time at industry) indicates significant differences in the means for both the industrial and academic sides, although not for the student or the overall success (sig. = 0.76 (personally); 0.01 (industrial); 0.02 (academic); 0.76 (overall)).

Table 5.37: Comparing 'success' means by the proportion of time the student spends at industry

Time spend working at industry		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
less than 25%	Mean	3.73	3.28	3.75	10.77
	N	258	257	257	257
	SD	1.052	.985	.823	2.373
25%	Mean	4.03	3.55	3.81	11.39
	N	31	31	31	31
	SD	.912	.995	.980	2.390
50%	Mean	4.14	3.71	3.86	11.71
	N	14	14	14	14
	SD	.770	.994	.770	1.978
75%	Mean	5.00	5.00	4.00	14.00
	N	1	1	1	1
	SD	.	.	.	.
more than 75%	Mean	3.66	3.63	3.29	10.58
	N	38	38	38	38
	SD	1.021	.998	.984	2.332

[N = no. of cases; SD = standard deviation]

Several students mentioned in their suggestions to help improve collaborative research that there should be an industrial placement at the start of the collaboration so that students can have insight into the industrial partner and gain an understanding of what their expectations or needs are. Some CASE students also stated that the industrial placements should be longer.

iii) Student age

The primary questionnaire results (Appendix 5D) showed that the students' ages ranged from 21 to 55 years old. It is therefore interesting to explore the relationship between student age and perceptions of collaboration success, and to see if there are differences in the percentage of cases which encountered communication problems and timescale problems, as well as in the communication methods used, within different age groups. The specific question to be addressed by this element of the survey is:

- *Is there a relationship between student age and perceived collaboration success?*

Table 5.38 compares the 'success' means by student age group; no dominant patterns can be seen here but looking at the 'overall' 'success' means, it seems that in general, the means are slightly higher for students who are over 35 years old. A t-test comparing the means for 21 to 35 years old versus the means for 36 to 55 years old indicates that only the 'success' means for the industrial side are significantly different (sig. = 0.88 (personally); 0.04 (industrial); 0.85 (academic) & 0.31 (overall)).

Table 5.38: Comparing the 'success' means by student age group

Age group	N (no. cases)	*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
21-25	211	3.75	3.36	3.67	10.78
26-30	77	3.81	3.37	3.79	10.96
31-35	27	3.85	3.15	3.78	10.78
36-40	14	3.71	3.79	3.79	11.29
41-45	8	4.00	3.75	3.75	11.50
46-50	3	3.67	3.67	3.67	11.00
51-55	2	4.00	3.50	3.50	11.00

The means for the extent that the project is characterised by good management, by good communication and by mutual interest or need were also compared by age group (Table 25, Appendix 5H). No dominant patterns can be seen for management or mutual interest or need, but for communication the means are higher for students who are over 40 years old (mean = 4.50). The following cross-tabulation (Table 5.39) shows the percentage of students who encountered communication problems with their supervisors by age group. It shows that students who are over 40 years old have not encountered any communication problems.

Table 5.39: Percentage of students who encountered communication problems with their supervisors by age group

Age group	N (no. cases)	*Encountered any communication problems with supervisors?*		
		Yes	*no*	*not sure*
21-25	211	25.6%	73.5%	.9%
26-30	78	33.3%	62.8%	3.8%
31-35	27	33.3%	66.7%	
36-40	13	30.8%	69.2%	
41-45	8		100.0%	
46-50	3		100.0%	
51-55	2		100.0%	

Examining the means for different modes of communication (with supervisors) in different age groups does not show any dominant pattern (Table 26,

Appendix 5H). Looking at the percentage of cases which encountered problems with project timescales by age group (see Table 5.40), the percentages are lower for students who are over 35 years old and none of the students within the 46-50 and 51-55 age groups had problems with project timescales.

Table 5.40: Percentage encountered problems with project timescales by age group

Age group	N (no. cases)	*Encountered problems with project timescales?*	
		yes	*no*
21-25	187	37.4%	62.6%
26-30	72	45.8%	54.2%
31-35	24	45.8%	54.2%
36-40	13	30.8%	69.2%
41-45	8	25.0%	75.0%
46-50	3		100.0%
51-55	1		100.0%

5.3.9 Comparison of responses from CASE & EngD students

The CASE (Co-operative Awards in Science & Engineering) scheme differs from the Engineering Doctorate (EngD) in that students involved in the former spend a minimum of 3 months at industry over three years, whereas EngD students are expected to spend about three quarters of their time working directly with the collaborating company. Also the EngD programme specifies a four year course and includes training in business studies (MBA) to prepare students for a managerial career in industry. In this section, significant differences in the CASE and EngD student responses are reported. The specific question to be addressed by this aspect of the survey is:

- *Are there any significant differences between the CASE and EngD student responses?*

Of the 348 students who completed the questionnaire, 248 were CASE students and 64 were EngD students. Most (84%) of the CASE students spend less than 25% of their time at industry, whereas nearly half (47%) of the EngD students spend more than 75% of their time at industry.

Looking at the students' motivations for doing their particular project rather than a standard PhD (Table 27, Appendix 5H), 'money' is the most frequently mentioned motivation for CASE students whereas 'industrial experience' is more important for EngD students. Of the benefits that the students gain from the industrial side (Table 28, Appendix 5H) 'access to industry's facilities' is the most important benefit for CASE students whereas 'gaining industrial experience' is the most significant for EngDs. The benefits that the students gain from the academic side (Table 29, Appendix 5H) are very similar for both groups.

Looking at the ratings that the EngD and CASE students provide for the industrial and academic motivations for doing a collaborative project, the modes for all the industrial motivations are different for the two groups except for 'to extend their knowledge base' and 'access to students' (Table 5.41). The CASE students seem more 'uncertain' about most of the industrial motivations compared to EngDs (see uncertain percentages in Table 5.41) again, probably because they spend less time with industry than EngDs. For all the academic motivations, the EngD and CASE ratings are similar except for 'to access industry facilities' (Table 5.42).

Table 5.41: CASE & EngD ratings for industrial motivations

Industry's motivations	**Modes** (1 = 'not at all true'; 5 = 'very true')		**% uncertain**	
	CASE	**EngD**	**CASE**	**EngD**
To extend knowledge base	5	5	5%	3.3%
To have access to university facilities/resources	1	3	11.3%	3.3%
To have access to students	3	3	18.4%	6.6%
To boost their sales/income	1	4	19.1%	14.8%
To avoid in-house investment in long-term/riskier projects	1	4	23.1%	19.7%
To have immediate problem solving	1	3	13.8%	4.9%
To raise their profile within society	4	1	16%	16.4%
To obtain prestige in marketplace	1 & 2	3	22.3%	18%

Table 5.42: CASE & EngD ratings for academic motivations

Academic's motivations	Modes (1 = 'not at all true'; 5 = 'very true')		% uncertain	
	CASE	EngD	CASE	EngD
To generate income	5	5	9.2%	3.3%
To find & work on real / industry's leading edge problems	5	5	6.4%	4.9%
To develop individual reputations	4	4	12.1%	11.5%
To see research being applied	4	4	5.3%	8.2%
To have an impact on society	4	4	11.4%	24.6%
To expose students to real world problems	4	4	7.8%	4.9%
To improve employment opportunities for students	4	4	6.4%	4.9%
To have access to industry facilities	4	3	6.4%	9.8%

Exploring the benefits that the industrial partners gain from CASE and EngD projects, the most important benefit from CASE projects is considered to be 'access to academic knowledge or expertise' whereas 'cheap research' is the most frequently mentioned benefit that they gain from EngD projects (Table 30, Appendix 5H). The most important benefit that the academics are perceived to gain from CASE projects is 'money', whereas having 'links or contacts with industry' is more significant in EngD projects (Table 31, Appendix 5H).

Looking at student responses to questions about their supervisors (Table 32, Appendix 5H), a higher percentage (30%) of EngD students encountered problems when carrying out their project due to differences between the partners than did CASE students (20%).

In relation to project management (see Table 5.43), the 'project specification' of most EngD projects is lower than that of CASE projects. A large proportion (80%) of EngD students has a Gantt chart or a list of deliverables for their project, whereas this was the case for less than a third of CASE students. The proportions of students who encountered problems in relation to project timescales, who had their project objectives or methods changed and who encountered personnel changes were higher for EngD projects. Also personnel changes in the coordination group had an effect on more EngD projects.

Table 5.43: Results related to project management: CASE versus EngD

Variable description	CASE (Mode/%)	EngD (Mode/%)
How well specified is project	4	3
Project management restrictiveness	2	2
Have Gantt chart/list of deliverables	32.7%	79.7%
Project timescales caused problems	31.7%	48.4%
Project objectives or methods changed	46.8%	64.1%
Partner providing most leadership (highest %)	academic 81.7%	academic 39.1%; industry 39.1%
Who coordinates/manages relationship (highest %)	academic 51.8%	both 46.9%
Encountered personnel changes	23.2%	37.5%
Personnel changes affected project	31.8%	45.8%
Have collaboration agreement in force	37.7%	26.8%
Asked to sign collaboration agreement	81.3%	41.2%
Asked to sign confidentiality agreement	44.7%	54.7%
Meeting frequency (highest %)	Quarterly 51.4%	Quarterly 67.2%

In most CASE projects (82%), the academic partner provides most leadership whereas in 39% of EngD projects the academic partner leads and for another 39%, the industrial partner leads. For most (52%) of the CASE students the academic partner manages the relationship, whereas in the majority of the EngD projects both partners do it.

A higher proportion of CASE students have a collaboration agreement in force for their project and 81% of these students were asked to sign the agreement. This was the case for just 41% of the EngDs who have an agreement. On the other hand, the percentage of students who are asked to sign a confidentiality agreement is higher for EngDs. Quite a high percentage of CASE students (40% compared to 16% for EngDs) have meetings less often (once a year or less).

Exploring the importance of email, phone and face-to-face communication for EngD and CASE students (Table 33, Appendix 5H) showed that for CASE students email is the most important means of communicating with their industrial supervisor, whereas for EngD students face-to-face is more important. A higher proportion of EngDs (39%) than CASE students (24%) encountered communication problems with their supervisors. For the majority of EngDs, these problems were with their academic supervisor, whereas for most CASE students the problems were with their industrial supervisor. On the other hand, more of the CASE students encountered communication problems between the industrial and academic partners (11.6% compared to 6.2% for EngD).

Comparing the means of the extent to which the project is characterised by good management, by good communication and by mutual interest or need for EngD and CASE students (see Table 5.44) shows higher means for CASE projects. A t-test indicates that the means for good management and for mutual interest are significantly different between CASE and EngD students (sig. = 0.04 & 0.02 respectively). The 'success' means for the student (personally) and for the academic side are also higher for CASE projects whereas the success mean for the industrial side is higher for EngD projects. A t-test indicates that the academic 'success' means are significantly difference between EngD and CASE students (sig. = 0.02).

Table 5.44: Responses related to project 'success': CASE versus EngD

Variable description	CASE (Mean)	EngD (Mean)
Extent characterised by good management	3.51	3.23
Extent characterised by good communication	3.64	3.45
Extent characterised by mutual interest/need	3.86	3.53
Success of collaboration personally	3.81	3.61
Success of collaboration for industrial side	3.35	3.47
Success of collaboration for academic side	3.77	3.45
Overall success	10.93	10.53

5.4 Summary

This chapter has described and presented the results of the second fieldwork activity; a questionnaire survey of students involved in industry-academia collaborative research projects. The general objectives of this survey were to test the theoretical perspectives of the research facilitators (Chapter 4) and to explore collaborative research from an experiential point of view. The questions that were posed at the beginning of the study, when designing the questionnaire template were: what are the determinants of successful collaborative projects?

and how do the issues raised in the interview survey (described in Chapter 4) impact project success? The 'success' of the students' projects was measured using several variables based on Likert scales and the influence of different factors were explored based on these measures ('success' means). The questionnaire survey responses were also analysed in the light of a series of 'additional' questions that emerged from the scoping studies (Chapters 2 & 3), the interview survey (Chapter 4) and the primary results of the questionnaire databases (Appendices 5D-5F). The findings are summarised as follows:

- It is evident that the students' responses on issues related to the industrial partner are influenced by their knowledge and experience of industry (which increases by year of project and by the proportion of their time that they spend located with the industrial partner). This indicates the importance of industrial placements and of planning such placements at appropriate stages of students' projects and ensuring that they spend enough time with industry (to ensure mutual understanding).
- Despite the various opinions and greater uncertainties regarding the industrial motivations for collaboration, it is clear that access to academic knowledge or expertise is considered important for industry. For the academic side, generating income and the opportunity to work on real problems are significant motivations.
- The most significant problems in collaborative projects from the students' perspective are project timescales, communication, different objectives or views on the project's direction, different reporting styles and issues related to publication or confidentiality. Interestingly, there appear to be more problems encountered as the project progresses and therefore the success measures do not significantly increase over time.
- The size of collaborating company is correlated with success in that projects with small companies are less successful and communication is more of a problem between academics and small companies.
- Personnel changes and changes in the project's objectives do not appear to be significantly correlated with project success, but they clearly need to be planned for at the outset.

- In relation to project management, some flexibility and some structure is characteristic of good management, and the existence of a collaboration agreement is not strongly associated with project success. The students did however emphasise the importance of planning and agreement at the outset of the project.
- It is evident that projects are more likely to be successful if both partners manage the relationship and if the partners have had prior collaboration experience. There is no evidence that, as some collaborative research facilitators suggest, collaboration is more successful if industry manages the project.
- The 'sectoral' variations (i.e. variations in projects funded by different research councils) in project success are evident in the type of industrial partner involved in the project. For example, NERC (natural environment) projects are more successful, perhaps because most of the industrial sponsors are research institutes which have similar working practices to academics. EPSRC (engineering & physical sciences) projects are less successful perhaps because they mainly involve manufacturing companies which have a different organisational culture (compared to academics). Collaborative projects which fall under the auspices of the ESRC (economic & social) seem to encounter more problems due to a lack of collaborative experience.
- The characteristics of 'successful' projects include: good understanding and high enthusiasm in the project by both industrial and academic partners, highly compatible supervisor disciplinary backgrounds, mutual interests and needs, prior collaboration experience, fewer problems in relation to timescales and effective communication (which therefore helps relationship building), and having a confidentiality agreement in place signed by the student.
- The characteristics of 'unsuccessful' projects include: low industrial understanding and enthusiasm in the project, poorly compatible supervisor backgrounds and therefore more problems due to differences

between the partners, meetings occurring less frequently (less than quarterly), poor management and more communication problems.

- The issues that are seen by students to affect their role in a project include timescales, confidentiality and publication of results.

In relation to the conceptual model described in Chapter 3, the questionnaire survey has enabled us to explore the process of collaborative projects in terms of success, problems, communication and management over time, as well as the attitudes of the various participants involved in the collaboration, including their motivations and issues related to their cultures (organisational or individual). The survey has also provided us with information on the variety in collaboration success between different industrial sectors (e.g. pharmaceutical & manufacturing) and by the size of the industrial partner. The succeeding chapter looks more explicitly at the results of the two core research activities and attempts to answer the research questions outlined in Chapter 3. It will provide a critique of the analysis undertaken and discuss how the findings inform the conceptual model described in Chapter 3.

6. Discussion of fieldwork data

The aim of this chapter is to draw together and integrate the findings of the two fieldwork activities described in Chapters 4 and 5: the interviews with the industry-academia collaborative research facilitators and a questionnaire survey of students working on projects jointly supervised by academics and industrialists. First a brief re-cap of the central ambition of this thesis and what has been achieved so far is provided (Section 6.1). This is followed by an assessment of how the findings of both surveys inform or support the current literature on industry-academia collaborative research (Section 6.2). The third section (6.3) explores the level of agreement or disagreement in the perspectives of the collaborative research facilitators and the students. Section 6.4 looks at how the research results have contributed to the conceptual model described in Chapter 3. The purpose of this chapter is to help us respond to the research questions specified in Chapter 3 (Section 3.2) as well as draw out the implications of the research findings for the planning and management of industry-academia collaborative research in the next, and final, chapter of this thesis (Chapter 7).

6.1 A brief re-cap

Recent government level studies on the relationships between industry and academia suggest that increased collaboration will bring significant economic benefits to the UK (Lambert, 2003). The main objective of this thesis is to identify the main barriers to effective industry-academia collaborative research, and therefore identify ways in which such collaborations can be improved. The background to the research described in this thesis (Chapters 2 & 3) demonstrated the complex nature and increasing importance of industry-academia collaboration. Key areas of concern and study include the various factors that encourage cooperation, the diverse disciplines (both professional & academic) that are involved, the motivations of the different participants, the barriers to collaboration, and the ways of managing and evaluating such interactions. The literature review in Chapter 2 indicated a need for further in-depth research on factors that influence the effectiveness of collaborative research, in particular those related to individuals who are involved in such collaborations (e.g. personal competencies, attitudes, understanding, etc.).

Several research questions were formulated to support development of our understanding of the factors that influence the effectiveness of the collaborative process. From the research background (Chapters 2 & 3), it was suggested that the effectiveness of industry-academia collaborative research depends to a degree on the following key elements: i) 'Motivations & Objectives' for collaborative research; ii) 'Communication' between collaborative partners; and iii) 'Management' of the collaborative processes. These key elements led to the development of a primary research question and three secondary research questions on which the research is based (P1, S1, S2 & S3; Section 3.2, Chapter 3). A new conceptual model was also developed to describe the role of these elements in industry-academia collaboration in terms of collaboration structure, the collaborative process and the attitudes of collaborative participants (Figure 3.1, Section 3.3). The model has a number of possible uses. For example, it can be used as a descriptive framework to foster greater understanding of the nature of industry academia collaborations, as a theory to test the importance of particular factors influencing collaboration effectiveness and as a framework for planning and managing industry-academia collaborations (see Section 7.2.1). In this study the model helped direct the research activities described in Chapters 4 and 5 and was used to explore and describe the significance of the three key elements for the effectiveness of collaborative research.

To help answer the research questions and test the conceptual model, two fieldwork activities were designed with the general objective of obtaining and analysing individuals' reflections and perceptions of their experience of industry-academia collaborative research. The first research activity served to explore the perspectives of industry-academia collaborative research facilitators via an interview based survey and the second activity obtained the perspectives of students working on projects jointly supervised by academics and industrialists through an online questionnaire. The collaborative research facilitators provided a 'theoretical' insight on collaborative research (i.e. what should happen) and provided information on how they organise and manage collaborative projects and networks. The students gave a 'coal-face' perspective on collaborative research (i.e. what does happen) and provided information on the process or implementation of collaborative projects. The results from the interview survey were used to guide the student survey so that the theoretical perspectives of the collaborative research facilitators could be tested, particularly on issues that are believed to influence collaboration success.

The findings of the two surveys are discussed further in the next three sections in terms of: (a) how they contribute to the current literature on industry-academia collaboration, (b) how the perspectives of the collaborative research facilitators compare with those of the students and, (c) how the results inform the conceptual model developed in Chapter 3.

6.2 How the fieldwork results inform the current literature

Reflecting the literature review in Chapter 2, the findings of the two fieldwork activities confirmed the complex nature of industry-academia collaborative research in terms of the wide variety of issues that can either enhance or impede the effectiveness of such interactions. The interview and questionnaire surveys enabled us to explore collaborative research from both a theoretical and an experiential perspective, as well as from a temporal aspect, i.e. investigate changes in the collaborative process over time. To date no previous studies in the literature appear to have taken a similar approach to that adopted in this thesis (i.e. explore collaborative research from all 3 aspects - theoretical, experiential & temporal). The literature review showed that there is a lack of in-depth studies exploring the cognitive or intellectual aspect of collaborative research in the UK.

The findings of the student survey will contribute usefully to the literature as no in-depth research is believed to have been carried out to date on the experiences or perspectives of students involved in industry-academia collaborative projects and there is increasing concern in recent years about their involvement in such projects (e.g. Barnes *et al.* 2002; Starbuck, 2001). In the next six sub-sections, we will go back to the 'gaps' in knowledge or questions that emerged in the literature survey (Chapter 2) and see if the research findings have helped us 'fill-in' these gaps or confirm/refute previous findings. Each of the following sub-sections corresponds to one of the aspects covered in Chapter 2.

6.2.1 Interaction mechanisms & types of relationship

The literature review indicated a need for further understanding of the characteristics of 'collaborative research', for example, what is the appropriate structure for such interactions in terms of size (number of people), duration, type of research, etc., and what roles should the various participants involved play in the collaboration? The various elements that make up the 'structure' of collaboration were shown in Figure 3.2 in Chapter 3. In the collaborative research facilitator survey we were able to obtain information on the structure of collaborative research projects and networks, and the student survey enabled us to acquire greater understanding of the structure of collaborative projects involving students.

Firstly, the size of a collaborative research activity can range from a joint research project involving just two individuals to a large multi-disciplinary and multi-national network involving many tens of participants. For collaborative projects involving students (e.g. EngD & CASE) a few students in the questionnaire survey commented on the difficulties of having too many supervisors or collaborators, in particular with regard to how this affected communication and arranging meetings. In the interview survey, one respondent pointed out that collaboration should be between organisations not individuals, otherwise it is too fragile because of the risk of individuals leaving the relationship. With regard to collaborative networks, some research facilitators warned of the risks of losing the benefits of informality if a network is too formal or procedural. There is, however, a belief amongst several respondents in the interview survey that large multi-partner or multi-national networks need to be more formal because of the number of people involved and the challenges presented by cultural and language differences.

The type of research appropriate for industry-academia collaborative research is clearly research that involves both basic and applied aspects which benefits both industrial and academic participants and which enables knowledge exchange, generation as well as application. As Konecny *et al.* (1995) point out, having a balanced mixture of basic and applied research aspects enables mutual understanding of each other's capabilities, needs, obligations, attitudes and roles. This type of research is defined by some authors in the literature as 'pre-competitive' research - research that is 'curiosity-driven' but more relevant to 'real' problems (AURIL, 1997; Lambert, 2003). The research is sufficiently removed from an end product or process for the industrial partner to feel comfortable working openly with other organisations and it enables academics (or students) to carry out quality research on 'real' problems over longer and more flexible timescales.

The duration of collaborative research is very important as the research findings reported in Chapters 4 and 5 indicate that it is best to arrange long-term collaborations (as opposed to short-term) because it takes a significant amount of time to establish a successful collaboration. Although many industrial partners (especially small companies) have a preference for shorter timescales, they need to understand that the quality of the research is unlikely to be high if the timescale is short (< 3 years). Relationship building involves the gradual development of mutual understanding, a joint language, a good personal relationship, and most important of all, mutual trust. Barnes *et al.* (2002) point out that it may be unrealistic to expect companies, especially those who have not collaborated together before, to demonstrate trust over a three year timescale. There is evidence in the student survey that participants who have collaborated together before have more successful relationships and several students commented on the benefits of having supervisors that already have a good long term working relationship. How receptive the research funders (research councils) may be to such a criterion being used to select research proposals is, of course, debatable. However, proposal forms do not currently request such information.

The roles of participants involved in collaborative research will vary depending on the research objectives, but in both surveys there were indications that equal contribution and attention by all participants in collaboration ensures mutual benefits. One research facilitator emphasised that if less than a quarter of the work is carried out by either partner, the relationship could not be classified as collaboration. There were comments by some respondents in the student survey concerning a lack of input or attention from their industrial partner and a lack of understanding by industry regarding the student's role in the project. Similar problems have also been highlighted in the literature (Barnes *et al.* 2002; GUIRR, 1999). It is therefore important to clarify the roles of all participants at the outset. Procedures also need to be set up to ensure that all participants contribute equally to the collaboration.

Concerning geographical distance, there are conflicting views on its effect in the literature (e.g. Stewart, 1999) but it is shown to be quite important for students because they need to spend some time at both institutions and to have face-to-face meetings with both partners. Personal contact is proved in both surveys to be correlated with successful collaboration and if the partners are at a great distance from each other it is more difficult to meet in person regularly. As indicated in the literature review, face-to-face communication helps tacit knowledge transfer, the development of a joint language and mutual trust. In his review, Lambert (2003) also expresses the view that proximity does matter, especially for small companies.

In the collaborative research facilitator survey there was evidence that some successful collaborations resulted from serendipity, i.e. the right people met at the right time. Lambert (2003) also believes that the most exciting collaborations arise as a result of like-minded people getting together, sometimes by chance, to address a problem:

> *'Great ideas emerge out of all kinds of feedback loops, development activities and sheer chance'.* (Lambert 2003, p.12)

It is therefore important to build dynamic networks between academics and industrialists, to increase the chance that people with common interests and goals will meet and develop (more formal) partnerships. Keeping networks refreshed by new members also helps avoid the risk of running out of ideas but procedures need to be developed to ensure that such 'new blood' are aware of how the network works in terms of how existing members work and communicate together (language, etc.).

6.2.2 Motivations for & benefits to collaboration

A wide range of motivations for and potential benefits from industry-academia collaboration were identified during the literature review. Because of the wide variety in opinion and findings on this aspect, there was a need to investigate what the industrial and academic motivations (& benefits) are for collaborative research in the UK, and subsequently to explore whether the different motivations of the various parties have an important influence on collaboration effectiveness. In the collaborative research facilitator survey, most of the identified motivations were similar to those revealed in previous studies (e.g. Molina *et al.*, 1997; Table 2.2, Chapter 2). The motivations are evidently related to the organisational cultures and circumstances of the industrial and academic participants. Because there are many different types of industrial and academic institution, with individual variations within each institution, it is not possible to generalise on the motivations for different partners. It is therefore important to clarify at the outset of (or before) every collaboration the participants' motivations both at the individual and at the organisational level.

The research findings support the suggestion made by Lee (2000) that the most important motivational consideration for academics is to advance or complement their own research agenda, for example, to secure funds for research, to find new problems to work on or to test the application of their research. According to Becher and Trowler (2001), it is a common finding of studies of academic motivations that what drives them are mainly factors inherent to the discipline itself, particularly the desire to develop a reputation in the field and to contribute significantly to it. There is, however, evidence in the literature (Chapter 2) that external pressures, in particular reduced funding from the UK government, are encouraging many academics to collaborate with industry. With regard to what motivates industry to collaborate with academics, the respondents in both surveys gave a diversity of answers. This appears to be due to the variety of 'industrial' partners in the student survey (e.g. craft-based or science-based companies, charities, government organisations, etc.) which may have different motivations for collaboration. The variation in motivations by type of industrial partner needs to be checked by further analysing the student survey database which could not be achieved as part of the study reported here because of time constraints. Also there appears to be a lack of awareness by some respondents in the surveys, especially the students, regarding why industry wants to collaborate. It can however be concluded from the research findings that for most industrial partners, their most important motivation for collaborative research is to acquire or extend their knowledge, which is consistent with what several previous studies have found (e.g. Tijssen, 1998; Senker *et al.*, 1998).

Motivations to collaborate also vary by type of collaboration with the student survey results revealing a number of 'additional' motivations or benefits that the industrial and academic partners have for participating in projects involving students. These include: having access to students to help out with the research, potential recruitment of the student by the industrial partner after the project, and exposing students to the real world (industrial training). Several authors in the literature emphasise that many companies regard the exchange or employment of educated and highly skilled personnel (graduates) as the most important benefit that they gain from universities (Hicks *et al.*, 1996; Tijssen, 1998; BHEF, 2001, OECD, 2002). The benefits 'having access to students' and 'potential employees' were only the fourth and eighth most frequently mentioned benefits in the student survey. This may be because most of the students in the survey spend less than 25% of their time at the industrial organisation thereby limiting personal contact and tacit knowledge exchange.

Although the two parties have diverse motivations for collaboration, they clearly complement each other in several respects including knowledge and skills, human resources and physical resources. Many respondents in the collaborative research facilitator survey emphasised the importance of mutual benefits for successful collaboration. In the student survey it was evident that the benefits that the industrial and academic partners gain match closely with their motivations which is important as it helps maintain the enthusiasm of the partners and helps promote the continuing success of the project. Statistical analysis of the student survey results demonstrates the importance of participant enthusiasm for the perceived success of collaboration. Balancing the needs of both parties is necessary to ensure mutual benefits and this requires mutual understanding and willingness to find a solution that would benefit all parties equally (Barnes *et al.*, 2002). Finding 'additional' benefits such as training, workshops, etc. can help balance the needs of both parties.

There have been indications in the collaborative research facilitator survey that industrial partners often do not benefit significantly from collaboration because their motivations or objectives change over time. This is likely to be a problem if the nature of the collaboration (in terms of outcomes) does not meet their 'new' objectives, as it is clearly the original motivations and objectives of the participants that determine the type of collaboration set up in the first place. Finally, it is also worth noting here that 'building or developing links or contacts (with industry/academia)' was frequently mentioned in the student survey as a benefit that the industrial and academic partners gain from their projects. This benefit was not revealed in the literature review and is important for the future of collaborative research – it matches the motivation that industrialists and academics have for getting involved in collaborative networks.

6.2.3 Barriers to & problems of collaboration

In the literature review, the most common barriers or problems that were identified in industry-academia collaborations were related to institutional differences (different cultures & structures), information dissemination restrictions due to confidentiality issues, intellectual property rights and ineffective communication. The significance of such barriers or problems in collaborative research was investigated further in the two surveys described in this thesis and we also explored whether such problems can be overcome. The student survey also enabled us to look at the problems that occur in collaborative projects involving students, which as mentioned earlier, is a new area of concern in the literature.

The most important barriers or problems mentioned by the survey respondents are indeed related to the different organisational cultures and working practices of industry and academia. The types of problems that were suggested include differences in their (industry & academia) research objectives, expectations, timescales, language, reporting styles and requirements with regard to publication or confidentiality. The findings support the comments made by Santoro & Gopalakrishnan (2000) that organisational culture is an important factor influencing knowledge transfer; it influences the actions of individuals by imposing a range of skills, habits and values, and it determines the kinds of knowledge sought and acquired as well as the types of knowledge building activities that are tolerated. The collaborative research facilitators revealed a range of different attitudes within academia, for example, 'pure', 'entrepreneurial' or 'applied' academics. The institutional context (culture & structure) clearly affects the priority that academics give to collaboration; for example, 'traditional' universities place more emphasis on knowledge acquisition whereas 'research' universities are more concerned with knowledge application and therefore do more work with industry (Becher & Trowler, 2001).

There have been some indications that the RAE (Research Assessment Exercise) discourages academics, in particular traditional academics, from collaborating as it does not consider industrial collaboration as high value. This has also been highlighted by several authors in the literature (e.g. Lambert, 2003; OECD, 2002, Becher & Trowler, 2001). In his review Lambert (2003) came across a number of cases where academics deliberately decided not to work with business in order to concentrate all their efforts on raising their RAE rankings (because of its focus on purely academic benchmarks such as publishing papers in high impact factor journals). He points out that even if the RAE assessment process is reformed to reward collaborative research with industry, it will be years before university departments see the benefits. There is, however, evidence that some academics are becoming less isolated and more entrepreneurial. According to some collaborative research facilitators, universities are becoming more business oriented in their own activities and therefore the 'culture gap' is narrowing and industry is changing its perception of universities. This supports the observation made by Lambert (2003) that academics are now more likely to welcome the chance of working with industrial partners than used to be the case and that there are signs of a change of culture in many UK universities:

> *'They have cast off their old ivory tower image and are playing a much more active role in the regional and national economy'* (Lambert, 2003, p. 9)

Lambert believes that this trend has been driven in good measure by money, with universities being forced by economic circumstances to search for new sources of funds and equipment. This appears to be true as the research findings show that generating income is considered to be the most significant academic motivation for collaborating with industry.

Most of the comments in the research findings on industrial attitudes relate to their short term focus and concerns about the risks of collaboration (unpredictable outcomes & loss of confidentiality), in particular those of small companies, which also affect the priority they give to collaborative research. The cultural gap appears to be greater between academics and small companies, than that between academics and large companies, with the results of both surveys showing that these two groups have more problems communicating and working with each other. The student survey showed evidence of lower perceived successes and more communication problems between the industrial and academic partners in collaborations with small companies compared to those with large companies. The differences between academics and SMEs (small & medium sized enterprises) is also highlighted in the literature by Stewart (1999) who also points out that their attitudes are now slowly being modified as they become more familiar with each other. This familiarisation process is not helped by the fact that only a quarter of the collaborative projects in the student survey involved SMEs although such companies constitute a significant proportion of the UK industry (in terms of number of businesses, turnover as well as employment, Konecny *et al.* 1995).

There was also evidence of different attitudes amongst students involved in collaborative projects as a function of their previous background; as the following statement from one respondent shows:

> *'Coming from an industrial background, [I] have found the laidback approach of university very hard to come to terms with initially'.* (RQUI)

Collaboration effectiveness also varies according to the sector that the industrial partner works in; for example, science-based (e.g. pharmaceutical) and craft-based (e.g. water utilities) sectors. The research findings support Stewart's (1999) observation that science-based firms have fewer problems with academics because they share similar values, whereas craft-based traditional firms have more difficulties communicating with university researchers because their cultures are very different. Some of the respondents in the collaborative research facilitator survey mentioned that the pharmaceutical industry is used to long-term research and that individuals working in this sector have more compatible disciplinary backgrounds with those of academics. Analysis of the student survey results demonstrates that compatibility of the industrial and academic participants' backgrounds is positively correlated with the perceived success of collaboration. An evaluation of collaborative projects involving water companies and pharmaceutical companies in the student survey showed that collaborations with water companies are more likely to encounter problems due to differences between the partners, project timescales and communication, compared to those with pharmaceutical companies. This indicates that more support is needed for collaborations involving craft-based organisations.

The student survey results also show that collaborations in the 'natural environment' research field are more successful and encounter fewer problems than those in the 'economic and social science' field. This could be because many of the collaborating institutions in the natural environment field are research institutes which are '*quite academic based*' as one student put it. For the social science field, industry-academia collaboration is a relatively new experience and the industrial and academic participants within this field have quite different organisational cultures. There is very little information in the literature about industry-academia collaboration in the social science field compared to other fields such as biotechnology and engineering although such collaborations are very important for social researchers because of the access to the workplace or company resources for their research. In the student survey we also obtained information on the professional or educational backgrounds of the industrial and academic supervisors but this data has not been analysed in depth. Analysis of this data would enable us to explore for example, how differences in educational qualifications and professional disciplines (e.g. manager, engineer, scientist) affect collaboration. This would be useful information for interdisciplinary collaborations which, as demonstrated in Chapter 2 (& by the bibliometric study in Appendix 2A), have become increasingly important in recent years.

With regard to personnel changes during industry-academia collaboration, some authors in the literature believe that they are 'disruptive' and are more commonly associated with SMEs (Barnes *et al.* 2002; BHEF, 2001). The student survey results show that such changes are not significantly associated with the perceived success of collaboration and that such changes happen as frequently in collaborations with large companies as in those with SMEs. Personnel changes are however a problem where the student finds it difficult to liaise with their new industrial contact because they do not have the same attitude (e.g. enthusiasm, understanding) or competence as their previous industrial supervisor. This indicates a need for procedures which ensure that there is an appropriate second contact in case personnel changes do occur. The second contact should have a similar attitude to the first person, i.e. have the same enthusiasm and competence. However, as pointed out by the BHEF (2001), personnel changes are part of corporate life, thus researchers must expect such changes.

In the literature review, intellectual property rights (IPR) was stated to be one of the main causes of conflict found in partnership disputes between industry and academia. According to some respondents in the collaborative research facilitator survey, IPR has been a significant issue in the past. However the situation is seen as improving as both sides increasingly understand each other better and there are routine solutions as to how IPR is managed. Only a few respondents in the student survey appeared to have encountered major problems with IPR simply because it was not agreed at the outset of the collaboration. IPR is still a problem for those who are not aware of the solutions but according to one respondent in the interview survey, this can be relatively easily solved by educating people. There were some indications that universities are becoming more conscientious of IP than they used to be thereby causing problems for some companies. This appears to be a result of the culture change that some universities are undergoing; i.e. they are becoming more business oriented. In his review Lambert (2003) suggested the introduction of an 'IP protocol' to provide simple ground rules for negotiations and to encourage the flexible use of IP by universities and businesses. He believes that IP ownership should be 'proportionate' meaning that the party which makes the biggest contribution (intellectual as well as financial) should have first rights on IP ownership. This is not an easy solution for collaborative research where all the participants are expected to contribute equally.

In the student survey some respondents encountered problems with publishing and confidentiality, primarily because they are carrying out commercially sensitive research. This supports recent concerns in the literature about industry-academia collaborations affecting students' (& academics') publishing behaviour (e.g. Carayol, 2003, BHEF, 2001). The BHEF states that there should be procedures to ensure that collaborative research efforts do not hinder students' academic work by inappropriately involving them in confidential research or imposing restrictions on publication. Appropriate publication delays (e.g. 2 or 3 months) may however be an acceptable solution for some. In their study of six collaborative projects, Barnes *et al.* (2002) found that the students involved in the projects experienced difficulties due to frequently changing objectives, pressure to produce results quickly and industry's short term focus. Half of the respondents in the student survey reported in Chapter 5 encountered changes in their project's objectives but statistical analysis shows that these changes did not significantly affect the perceived success of collaboration. Problems with project timescales were quite significant in the student survey, affecting more than a third of the cases examined. This appears, as indicated in some of the comments made by the students, to be related to industry's short term focus and their lack of understanding of the nature of PhD level research.

Ineffective communication is shown in the literature review to be a common barrier in industry-academia collaboration. Communication problems were also quite significant in the student survey, particularly the lack of, or infrequent, communication between the students and their industrial supervisor. The statistical results show that communication problems, either between the student and their supervisor or between the industrial and academic partners, are associated with low levels of perceived collaboration success. There was evidence in both surveys of problems related to the use of jargon. One student mentioned the benefit of having jargon explained by both of his supervisors during meetings to ensure mutual understanding. Finally, with regard to whether the barriers or problems in industry-academia collaboration can be overcome, several collaborative research facilitators believe that many of what are seen as barriers are in fact 'hurdles' that can be overcome with time, particularly if there is willingness, understanding and trust between the participants. The student survey findings however show some evidence of increases in problems encountered as the collaboration progresses (by year of project) - this finding is discussed further in Section 6.3.2.

6.2.4 Management of collaboration & best practice issues

The literature survey revealed a wide variety of issues that need to be taken into account when managing industry-academia research collaborations. It also raised a number of questions including: how prescriptive or flexible should the management structure be for collaborative research? Would a standard management model be appropriate? And would a collaboration agreement help? The importance of appropriate communication methods was also emphasised in the literature review and therefore attempts were made during the two fieldwork activities to identify suitable modes of communication and meeting structure (e.g. frequency).

Reflecting the literature review, the findings of both surveys show how complicated it is to manage industry-academia collaborative research. Selected management approaches clearly depend on the structure and scale of a specific collaboration. Any particular management model is influenced by the research objectives, the expected outcomes (e.g. products, publications, etc.), and the number and type of collaborative participants involved (e.g. whether the project involves students). Therefore a standard management structure or model would not be appropriate for every case. It appears that, according to the survey of collaborative research facilitators, the management structure needs to be quite prescriptive for large scale (multi-partner & multi-national) collaborations because of the number of individuals involved and their associated cultural and language differences. Smaller collaborations however do not need such a formal structure and the results of the student survey prove this by showing that most EngD and CASE collaborative projects have a fairly flexible project management structure. The research findings also show that it is desirable to have an adaptive or responsive project management style in collaborative research, particularly where the research is 'curiosity-driven' and where changes in project direction and unexpected outcomes might be unavoidable. As mentioned in the previous section (6.2.3), half of the respondents in the student survey encountered changes in their project's objectives or methods. Other changes that may occur during collaboration include personnel changes and unexpected commercial benefits.

A standardised good practice model for collaboration management such as that developed by Barnes *et al.* (2002) (Figure 2.2, Chapter 2, reproduced here as Figure 6.1) could, however, be a useful tool for potential collaborators to help them become aware of and understand the various issues involved in managing collaborations.

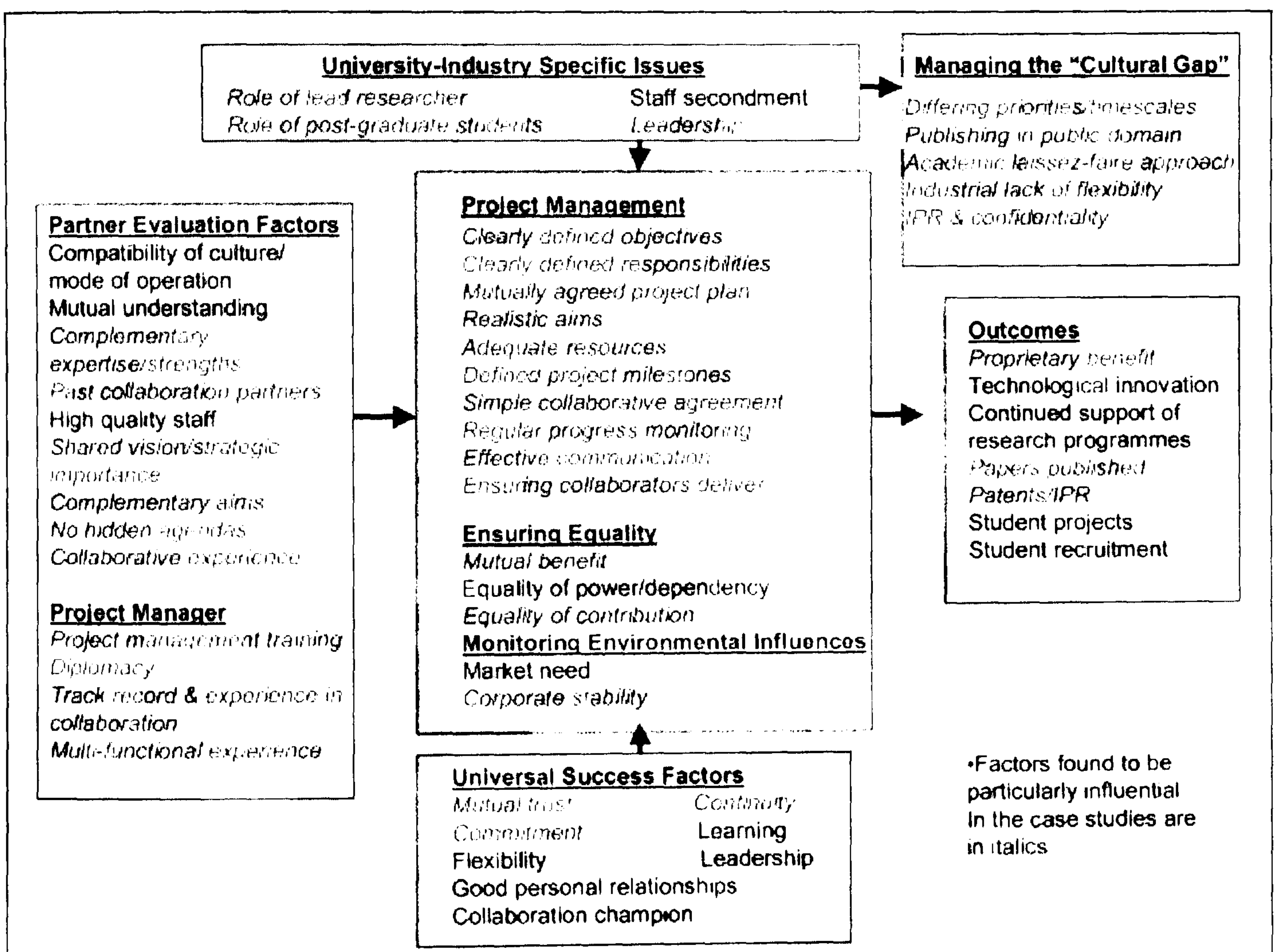

Figure 6.1: Good practice model for the effective management of collaboration (from Barnes *et al.* 2002; reproduced from Chapter 2, Figure 2.2)

In their model, Barnes *et al.* highlighted in italics factors found to be 'particularly influential' in the six collaborative projects that they studied. There are some other factors listed in their model that were not highlighted in italics but which were found to be particularly influential by the research findings described in this thesis, including: mutual understanding, learning, flexibility, good personal relationships and the influence of a collaboration champion. There are also a number of other issues identified in the findings here that have not been incorporated in Barnes *et al.*'s model including: flexibility in project management, compatibility of disciplinary backgrounds, and institutional context (e.g. attitudes & incentives for collaboration). The applicability of Barnes *et al.*'s model has therefore been found to be limited, suggesting that their model also needs further testing, and perhaps adaptation to suit different types of collaboration (e.g. long-term and short-term collaborative projects, small and large scale collaborative networks, etc.).

The student survey provided a great deal of useful information regarding the management of collaborative projects involving students. There is relatively little information in the literature on this aspect with the exception of recent papers based on forums of experienced collaborators in the US (e.g. BHEF, 2001; GUIRR, 1999). The results of the student survey show that most of the 'successful' collaborative projects have a fairly flexible project management structure which include a Gantt chart or list of deliverables. Although having a collaboration agreement in force is shown not to be significantly correlated with the perceived success of a project, several students emphasised that there should be careful planning at the outset of (or before) collaboration to ensure mutual understanding of expectations and timescales. Agreements should be set up to sort out issues like IPR and confidentiality to help protect the students' academic interests, particularly where the research being conducted is commercially sensitive. The results support the proposition made by the BHEF (2001) that the student should also sign a confidentiality agreement if there is one in force. As Starbuck (2001) recommended, a few students suggested that they (students) should also be involved in planning the project and in setting up agreements on objectives, timelines, and confidentiality, etc. This was suggested as a way of helping to reduce uncertainties and enhance mutual understanding between all the participants.

Another important management related issue highlighted during the student survey is the planning of industrial placements, both the length of the placements and ensuring that they occur at appropriate stages of the students' projects. The results show that if students spend more time working at the industrial organisation, they are more likely to understand the needs of the industrial partner. Several students also commented that it would be useful to have a placement period at the start of collaboration so that they can gain some insight into the industrial partner and improve their understanding of what the industrial partner's expectations or needs are. Some CASE students mentioned that their industrial placements should be longer (than 3 months) and statistical analysis of the survey results shows that the collaboration is more likely to be perceived as successful if the student spends half of their time at the industrial partner's organisation. Spending more time at the industrial organisation enables more face-to-face contact with the industrial partner, facilitating tacit knowledge exchange and therefore mutual understanding. Equality also appears to be important here with higher perceived successes for both the industrial and academic participants if the student spends the same amount of time at each organisation. Procedures also need to be put in place when planning industrial placements that ensure that students are not treated as "employees" or asked to do work that is not related to their project whilst located at the industrial organisation.

With regard to setting up collaboration agreements, it is clearly a problematic issue particularly for those who are collaborating for the first time. The negotiation process is also complicated by the different languages, motivations, objectives and working practices of industrialists and academics. The results from the interview survey show that, although they recommend that there is a collaboration agreement in force, the Research Councils do not provide any support on how to set up an agreement because they pass the responsibility on to the universities. According to one research council interviewee, the research councils cannot force a company and a university to sign a collaboration agreement, so they generally maintain a distance from this matter by simply saying that there should be an agreement but not specifying what the agreement should include. Another respondent referred to a standard 'model' collaboration agreement available on the government LINK scheme website (www.ost.gov.uk/link) which was developed by both university and industry representatives and which covers a large number of different aspects of collaboration. This was set up to help participants prepare an agreement for collaborations established under the Government's LINK scheme. There are however, as Lambert (2003) points out, no model contracts for collaborations that are not working through the LINK programme. Lambert believes that this problem could be addressed by making a small set of model contracts, which cover various approaches to IP ownership, management and exploitation rights, available to business and universities to be used on a voluntary basis. In the interview survey, several research facilitators also stated that model agreements could help the negotiation process but that they need to be adaptable to suit particular collaborations. However, as pointed out by the BHEF (2001), model agreements are difficult to develop and implement because business practices in different industry sectors (even within the same company) demand disparate agreements.

With regard to the question of who should manage industry-academia collaborative projects, the collaborative research facilitators had a diversity of opinions on this but statistical analysis of the student survey results indicate that collaborations are more likely to be perceived as 'successful' if both partners take a role in managing the relationship. Again this indicates the importance of equal contribution in collaborative research. Lambert (2003) also believes that there should be careful and consistent management by both sides in collaboration. In the collaborative research facilitator survey the role of 'relationship managers', 'champions' or 'facilitators' came across strongly (particularly for long-term relationships) which is interesting because there is very little mention of this in the literature. Just one source identified during the literature review indicated the necessity of a 'champion' within the sponsoring company who is dedicated to making the partnership work to ensure successful collaboration (BHEF, 2001). Another author reported on the limited success of liaison offices as facilitators mainly because some of them only work to initiate contacts and they do not have high visibility and status (Konecny *et al.*, 1995). Findings from the interview survey show that some respondents believe that industrial liaison managers should progress and maintain contact with the relationship on an informal basis. Other respondents state that there should be an individual at each end, i.e. one on the academic side and one on the industrial side, who ensures that the collaboration is working well so that the relationship is maintained following completion of a project. Such individuals need to have appropriate skills and experience of both industrial and academic environments (i.e. understand the different languages, cultures, etc.). According to Stewart (1999), the competence and attitude of industrial liaison officers can influence the successful formation of a partnership. One student commented that research contract departments within universities should be trained to understand the needs of industry and should read guidelines on industry-academia collaborations.

As was found during the literature review, the importance of face-to-face communication was emphasised in both surveys. Although email is the most important method for many students for communicating with their industrial supervisors, some commented that they would prefer to have more face-to-face meetings with their industrial sponsor. Several respondents in the collaborative research facilitator survey believe that face to face meetings make it easier to reach agreements about ways forward and also to use other communication methods between meetings. That meetings should take place regularly is supported by the student survey results which indicate highest perceived successes for the industrial and academic partners if meetings are held more frequently than once a month. Dodgson (2001) points out that tacit knowledge exchange is not easily transferred unless there is frequent, effective and continuous communication.

It is therefore concluded that appropriate approaches for managing industry-academia collaboration are dependent on the type of research being performed, and the number and type of participants involved. It is difficult to design an appropriate management strategy for collaborations involving 'curiosity-driven' research because the outcomes are unpredictable and an adaptable approach is necessary. In long-term collaborations involving pre-competitive research, 'relationship' management appears to be more important than 'project' management. This distinction was also highlighted by one source in the literature which suggested that collaborations which involve basic, exploratory research require a 'partnership management' approach whereas research of a more applied nature (e.g. problem-solving) is managed like 'research contracts' (BHEF, 2001). Good personal relationships and mutual trust between participants are essential for successful long term collaborative relationships. Thus it is important to nurture and manage the relationship between participants. Relationship management might involve monitoring the relationship between participants via subjective measures (e.g. satisfaction), ensuring that there is good communication and mutual understanding, and resolving any 'attitude' related conflicts. On the other hand, a more project management approach would involve planning and managing the research objectives, methods, timelines, results, participants' roles and meetings, as well as setting up agreements on IPR, confidentiality and publications.

6.2.5 UK government incentive schemes

As indicated in the literature review, the UK government has over recent years, provided a growing volume of funding schemes specifically designed to encourage collaboration. The effectiveness of current schemes for supporting industry-academia collaborative research was explored further in the interviews with the collaborative research facilitators, in particular 'people based partnership' schemes such as LINK and collaborative networks funded by the EPSRC. The student survey also enabled us to explore the effectiveness of the Engineering Doctorate and CASE schemes. It must however be noted here that the research in this thesis focused mainly on issues related to the three key elements that the research questions are based on: motivations and objectives, communication, and management. Therefore, the impact of government policies and schemes was not explored in great detail.

There were some criticisms in the collaborative research facilitator survey with regard to complex collaborative schemes such as LINK, the UK government's main mechanism for promoting pre-competitive research between industry and academia. One respondent believes that such schemes discourage people from collaborating because of the length of time it takes to set up the collaboration due to the bureaucracy associated with it (application, approval, auditing, etc.). Lambert (2003) however points out in his review that there has been real progress in the LINK scheme recently in that the time from application to project start has been reduced from 52 to 22 weeks. This indicates that, as mentioned by one respondent in the interview survey, the government schemes are improving and becoming more realistic, mainly because they are learning from experience or by observation. This learning process however may be restricted by a phenomenon observed by some collaborative research facilitators, that people involved in collaborative schemes sometimes do not report failure.

There were indications from the interview survey that some collaborative schemes are being oversold to small and medium sized companies (SMEs) resulting in unrealistic expectations. Also schemes like LINK have a disadvantage from a small company's point of view because of the large amount of contribution required. The government schemes are also stated by one research council interviewee to be more of an effort for social scientists as they do not fit neatly with how they operate. The potential support organisations within the social science sector are not as wealthy as those in other sectors such as engineering and medicine. The student survey also revealed that most participants in the ESRC (Economic & Social Research Council) funded projects have not worked together before making collaboration a new experience for many social scientists. This therefore indicates the need for more support and more realistic schemes for SMEs and for fields like social sciences. This finding supports the comments made by Stewart (1999) that policies need to be tailored to recognise the needs of individual sectors.

The student survey showed that schemes such as the Engineering Doctorate and CASE programmes provide a wide range of valuable benefits to industrialists and academics including knowledge exchange, financial support, access to students, and providing the opportunity to conduct relevant research (both theoretical & applied). Compared to the CASE scheme, the Engineering Doctorate appears to offer greater benefits to students in terms of providing them with more industrial experience and face-to-face contact with the industrial partner. Many CASE students in the questionnaire survey were uncertain about what their industrial partner wanted from the collaboration due to a lack of understanding or industrial experience. It is therefore important to ensure that these 'personal mobility' schemes are well planned in terms of using approaches that enable sufficient mutual understanding (tacit knowledge exchange) between the participants including adequate face-to-face meetings and appropriate industrial placements (see Section 6.2.4). The findings support the observation made by Saussois (2001) that policymakers promoting schemes that introduce students to the corporate world (referred to as 'socialisation phase') need to be aware that it is not a straightforward but a 'trial and error' process involving emotions, feelings and behaviour. He recommends setting up organised feedback where policymakers can listen to students' reactions and questions about the corporate world.

6.2.6 Evaluation of industry-academia collaboration

The literature survey highlighted difficulties and uncertainties in how to define and measure the effectiveness of industry-academia collaborative research. This indicated a need for further research on how various individuals who are involved in collaborative research projects or networks in the UK (in this case the collaborative research facilitators) define 'successful' or 'effective' collaboration and how they monitor or evaluate collaboration, i.e. what measures or metrics (objective and/or subjective) do they use?

Evaluating the efficiency of industry-academia collaboration is also shown in the collaborative research facilitator survey to be problematic, especially the measurement of 'softer' (subjective) metrics and long term impact (socio-economic benefits). It is however not an intractable problem as methods such as interviews or questionnaires could be used; perhaps like the student survey described in this thesis which enabled us to evaluate collaborative projects from the students' perspective. The main difficulty in evaluating collaboration is that the measures or definition for 'successful' collaboration are not the same for each participant, even the collaborative research facilitators, because they have diverse objectives for collaboration. There are many variables, both objective and subjective, that can be used to measure collaboration effectiveness but it is hard to prioritise them because of the differences in individuals' perception of success. There is evidently a tendency to focus on simple objective measures because they are easier to measure (e.g. number of people involved in network meetings, number of contacts, number of patents or papers and continuity of the collaborative relationship). Some of the research council interviewees stated that they usually evaluate collaborative activities at the end of the project but this approach has a number of disadvantages including that no evaluation is done during the collaboration, thus improvements cannot be made during the process, and that the long term impact is not measured. In the literature some authors suggested that there should be a set of metrics specific to the collaboration which is mutually defined by the industrial and academic participants at the outset (Saussois, 2001; Starbuck, 2001; NAS, 1997). These metrics can be used to measure collaboration success and satisfaction at different stages of a project and would therefore help continuous improvement in the processing, functioning, and effectiveness of a partnership.

There have been several indications in both surveys of the importance of feedback from collaborative participants and of sharing experiences, both successful and unsuccessful. Some respondents in the student survey suggested setting up forums for students involved in collaborative projects (like EngD & CASE) where they can share their own experiences and suggestions. There have been several papers published in recent years which report findings based on studies of forums of individuals with experience of industry-academia collaboration in the US and which are providing some helpful information and best practice guidance (e.g. NAS, 1997; GUIRR, 1999; BHEF, 2001). However, as pointed out in the literature review, there are variations in the nature of industry-academia relationships and incentive schemes between different countries so successful approaches or best practice in one country may not be applicable to other countries (Polt *et al.*, 2001). It is therefore suggested that similar forums are set up in the UK and that the outcomes of these forums are published to share information and best practice guidance for collaborative research in the UK.

6.3 Comparing the perspectives of the collaborative research facilitators & students

As noted in Section 6.1, one of the main objectives of the student survey was to compare the students' perspectives on collaborative research with those of the collaborative research facilitators (i.e. 'coal-face' v 'theoretical' perspectives). In the next four sub-sections the level of agreement or disagreement in the responses of these two populations are explored and discussed.

6.3.1 Motivations for collaboration

With regard to motivations for collaboration, the results showed that only two out of the eight motivations mentioned by the collaborative research facilitators as being pertinent to the industrial collaborators, were confirmed by the majority of the respondents in the student survey. Due to the type of research being carried out in the students' projects, i.e. long-term 'curiosity driven' or 'pre-competitive' research, it is clear why access to knowledge is a commonly recognised motivation whilst other motivations such as 'immediate problem solving' and 'boosting their sales or income' are not. It is difficult to compare the responses of the two groups here because the students had very diverse views on the suggested motivations for industrial collaborators, partly because many students were 'uncertain' about their industrial partner's motivations and partly because their responses are based on different types of industrial partners which have diverse motivations for collaboration (e.g. science-based, craft-based, charities, local government, etc.). As mentioned earlier in Section 6.2.2, the diversity of motivations by type of industrial partner needs to be further analysed. The motivations also vary by type of collaboration, for example, short term contract, long term project, collaborative network, etc. and the students' responses are based on just one type of collaboration whereas the responses of the collaborative research facilitators are more general.

However, there is agreement between the two groups on the significance of all the academic motivations identified by the collaborative research facilitators. The respondents in both surveys appear to have greater common understanding concerning why academics want to collaborate, possibly because they have more contact with academics. According to the collaborative research facilitators, different types of academic (e.g. eminent academics, 'traditional' academics, etc.) have different motivations for collaboration. This difference is not apparent in the student survey results but further analysis needs to be carried out to check, for example, what the motives are for 'traditional' and 'applied' academics and whether there are variations in academic motivations in different research fields (e.g. social science v. engineering). The comment made by some collaborative research facilitators that there is a reverse flow with regard to access to facilities because some universities cannot afford state of the art equipment is certainly true because the majority of respondents in the student survey believe that 'to have access to industry facilities' is a motivation for academics whereas 'to have access to university facilities' is not a motivation for industry.

6.3.2 Barriers & Problems

The student survey findings support comments made by several respondents in the collaborative research facilitator survey that organisational culture is an important issue in industry-academia collaboration. There is however one interesting difference in the responses of the two groups. Many of the comments made by the collaborative research facilitators on (culture/attitude related) problems in collaboration appear to relate to the academic partner, whereas the majority of the students' comments on problems that they have encountered relate to the industrial partner. It appears as if the research facilitators' knowledge of academic attitudes is based on their own experience of communicating with academics. It is also evident that most of the comments made by the collaborative research facilitators relate to problems that occur before, or at the outset of, collaboration; for example, issues that prevent academics and companies from collaborating (e.g. RAE & problems identifying suitable partners) and problems that occur in negotiations or agreements between the two parties such as the right to publish and IPR. Some of the collaborative research facilitators did mention that they have not, or have rarely, been involved at the coal-face of collaborative projects or networks and some respondents mentioned that they only get involved at the start of a collaborative relationship. There is also evidence that some students involved in collaborative projects may not be aware of problems that occur at the outset because many respondents (45%) in the student survey were not sure if a collaboration agreement existed and some students commented that they should be involved in the planning stages and in setting up agreements.

Many respondents in the student survey commented on the difficulties that they have encountered due to the different reporting style requirements of their industrial and academic supervisors. This is an issue that was not raised by the collaborative research facilitators. In addition, differences in desired or anticipated timescales did not appear to be a very significant issue according to some collaborative research facilitators, but over a third of the respondents in the student survey encountered problems with project timescales. Such problems were also shown to significantly affect the perceived success of collaboration. These are clearly issues that cannot easily be noticed by those who are not involved at the coal-face. There is conformity in the results of the two surveys that the effect of individuals' disciplinary backgrounds on collaboration varies by industrial sector, depending on the nature of the work that the collaborating organisations do, the type of people that work within these organisations and also how much collaboration experience the organisation (or individual) has. The student survey results support the views of some collaborative research facilitators that pharmaceutical companies work more successfully with academics and that collaborations between academics and small companies are more problematic due to cultural differences (timescales & communication). Statistical analysis of the student survey results shows that the compatibility of the partners' backgrounds is strongly associated with the perceived success of collaboration and this is an issue that the research councils need to be aware of as they are often trying to promote interdisciplinary collaboration.

Although several collaborative research facilitators commented that many of the barriers to industry-academia collaboration are 'hurdles' that can be overcome with time, the student survey results showed an increase by year of project in the proportion of projects encountering problems due to differences between the industrial and academic partners. As indicated earlier these are issues that the collaborative research facilitators are not aware of because they are not involved in the day-to-day management of projects. Timescale problems are deemed to happen more frequently in the latter stages of projects that are of long-term duration because of industry's short-term focus and thus their desire for quick results. Also problems in carrying out or reporting on the project are more likely to be noticed when results emerge and are being published (end of year reports or publications) which does not usually happen during the early stages of a project. There was clear evidence in the studies of decreasing enthusiasm, particularly from the industrial side, as collaborative projects progress (by year of project).

From the students' perspective however, there was some evidence that problems encountered at the start of projects are indeed overcome with time. The student survey results also show that for over half of the students, the relationship between the two parties (industry & academic) has 'improved' over time and for nearly two thirds of the students, the quality of communication has 'improved' over time. It appears that whether the barriers or problems can be overcome or not depends mainly on the attitudes (e.g. patience, enthusiasm & trust) and competence (e.g. understanding) of the participants. Time is an important element here as it takes time to develop a joint language and mutual trust, and this process depends on the participants' enthusiasm and competencies (e.g. ability to learn) as well as communication. Problems related to personnel changes, IPR and confidentiality can be overcome if appropriate measures have been put in place (e.g. agreements, suitable second contact, etc.).

6.3.3 Management & Communication

The importance of having a collaboration agreement in force was emphasised by several collaborative research facilitators but the student survey results show that having one in force does not significantly improve the perceived success of collaboration. However, as pointed out earlier, many students (45%) were not sure if there is an agreement in force for their projects and quite a few students emphasised the importance of good planning and agreements at the outset. Setting up agreements at the outset of a project would certainly ensure that issues such as IPR and confidentiality, which could cause major problems later on in the collaboration, are sorted out. In the collaborative research facilitator survey there were diverse opinions on who should manage collaboration but a few respondents did believe that it is best not to leave the management to academics. The student survey results show that projects which are managed by the academic partner have higher 'success' means than those which are managed by the industrial partner. But, as indicated previously in Section 6.2.4, the projects are more likely to be most successful if 'both' partners manage the relationship which allows equal contribution to the collaboration.

There is agreement in the findings of both surveys that prior experience of collaborating together promotes successful collaboration, with the student survey results showing that such experience is significantly correlated with the perceived success of collaboration. The results however do not support the belief that partners who have collaborated before encounter fewer problems with collaboration agreements than new collaborators. Further research is needed to find out what problems experienced collaborators are having when setting up agreements in order to be able to find appropriate solutions. With regard to communication, there is agreement in the findings from the two response groups that face-to-face communication and regular meetings are essential to collaboration success.

6.3.4 Factors contributing to 'successful' or 'unsuccessful' collaboration & 'best practice' suggestions

In the interviews with the collaborative research facilitators, the factors that contributed to 'good' and 'bad' examples of collaboration were identified and in the student survey the characteristics of 'successful' and 'unsuccessful' projects were explored. The results of both surveys show a number of similarities in the factors that contribute to 'successful' collaboration including enthusiasm, regular communication, and mutual interests or needs, and also in the factors that contribute to 'unsuccessful' collaboration including poor (infrequent or lack of) communication, personnel changes and a lack of enthusiasm or attention by participants. In the collaborative research facilitator survey, 'valuable or concrete outcomes' was frequently mentioned as a factor that is believed to help maintain successful collaboration. 'Concrete' outcomes are hard to predict in collaborations involving 'curiosity-driven' research. Valuable outcomes can however be expected in terms of the benefits that could emerge from collaboration including knowledge exchange, training, and making new contacts.

It is difficult to compare the results of both surveys here because the responses of the collaborative research facilitators are based on a relatively small number of examples. Also, the responses are based on different definitions of 'successful' and 'unsuccessful' collaboration. The student survey results are based on criteria developed during data analysis (see Section 5.3.3) and it is acknowledged that this is probably not the best way of defining such collaborations. It must also be noted here that some of the collaborative research facilitators found it difficult to provide examples of good or bad collaboration because they have not, or have rarely, been involved at the coal-face of collaborative research. Some of their responses were based on what they have heard or read about.

A wide variety of 'best practice' suggestions were provided by the respondents in both surveys and there are some similarities in the topics that were frequently mentioned including good management (better planning & agreements at outset), regular communication and clarity of expectations. Other topics that were suggested by both groups include promoting mutual understanding and having flexibility in the project management structure. There were some propositions made by the students that did not emerge from the collaborative research facilitator survey including better planning of industrial placements and ensuring that industry understands what the student's role involves. It should be remembered that the questions in the interview survey however did not specifically refer to collaborative projects involving students.

6.4 How the fieldwork results inform the conceptual model

In Chapter 3, a conceptual model was developed based on the knowledge gained from the research background presented in Chapter 2 (Figure 3.1). The model illustrates the significance of the three key elements that the research questions are based on: (i) motivations and objectives, (ii) communication, and (iii) management, for the effectiveness of industry-academia collaboration. It shows the relationship of these three elements to three collaboration 'characteristics': i) the 'structure' of collaboration, ii) the 'process' of collaboration and iii) the 'attitudes' of participants involved in collaboration. The purpose of the model is to use it as a descriptive framework or tool to help us gain greater understanding of the nature of industry-academia collaboration. It is designed to provide a clearer view of the multifaceted nature of this topic and to help gain greater awareness of the factors that influence collaborative research.

In the summaries of Chapters 4 and 5, and also in the previous sections of this chapter (Sections 6.2 & 6.3), we have seen how the findings of the two core fieldwork activities have informed the structure of the conceptual model. The findings have helped develop our understanding of the 'structure' of collaborative projects and networks, the effects that the 'attitudes' of industrialists and academics can have on collaborative research within different fields of research or industrial sectors, and the 'process' of collaborative research in terms of problems encountered and communication over time and those factors which help maintain successful collaboration. The results have also shown us the range of motivations that the industrial and academic partners have for collaborative research, a variety of mechanisms adopted or perceived to be appropriate for managing collaborative research projects or networks, and the significance of communication between the various participants.

The research findings provide an opportunity to make some modifications to the original model which was developed based on knowledge obtained from the research background described in Chapter 2 - these changes are discussed in the next sub-section. It is clear from the findings that no two collaborations are the same in terms of the three collaboration 'characteristics' (structure, process and attitudes) and that the three 'elements' (motivations/objectives, modes of communication & management approaches) vary for different types of collaborative ventures (e.g. collaborative projects involving students, collaborative networks, long term strategic partnerships, etc.). This indicates that the model will need to be tested on other forms of industry-academia collaboration. The model's value for the study of industry-academia collaboration is explored further in the next chapter (Section 7.2.1).

6.4.1 A revised model for industry-academia collaboration

The fieldwork carried out in this thesis has led to a fundamental re-evaluation of the conceptual model. Specifically, the study findings suggest that the three 'elements': 'motivations/objectives', 'communication' and 'management', are relevant to and should therefore be located on all three sides of the model, not just one side as the original model shows (Figure 3.1, Chapter 3). In effective or successful collaboration these three elements are interdependent. With regard to the motivations and objectives for collaborative research, the research findings support the comments made in Chapter 3 that they are related to the participants' 'attitudes' (individual & organisational backgrounds) and that they determine the type (structure) of collaboration set up. The findings also confirm that the different objectives of the industrial and academic participants (because of their different attitudes and backgrounds) can affect the collaboration process itself, particularly in the initial stages when agreements are being made. There is also evidence that changes in the motivations or objectives of the participants (most likely the industrial partner's) could occur during collaboration and may in turn influence the process. Another factor causing changes in objectives is the type of research being carried out, for example, 'curiosity-driven' research which involves unpredictable outcomes and therefore may lead to necessary changes in specific project objectives.

With respect to the communication element of the model, the research findings support the original concept that communication is influenced by the participants' attitudes (understanding & language) and can affect the collaborative process. However, the findings also highlight the importance of communication when the motivations and objectives for collaborative research are being shared both at the outset and during the research process. If the motivations and objectives are not clearly stated and understood, this could lead to the wrong type of collaboration structure being set-up and therefore disappointment if needs are not being met. Communication is also an important element in the management of collaboration. Good and clear communication is needed when setting up agreements and regular meetings are important for a successful collaborative process.

Concerning the management of collaborative research, the fieldwork results support the initial view made in Chapter 3 that the approach adopted depends on the structure of the collaboration and that management tactics can influence the collaborative process. The research findings also show the importance of 'relationship' management for reducing conflicts between participants which are related to their attitudes (e.g. cultural gaps, different objectives & communication related problems). Table 6.1 describes the difference between 'project' and 'relationship' management based on the understanding developed from the fieldwork.

Table 6.1: 'Relationship' & 'Project' Management in Collaboration

Relationship Management	*Project Management*
▪ Assessment of how relationship is going between participants via feedback & perceptions (subjective measures) ▪ Ensure good communication (informal) & mutual understanding to help develop mutual trust ▪ Conflict resolution – manage cultural gaps (e.g. timescales, expectations, communication) & attitudes between participants	▪ Day-to-day management & evaluation of project (objective measures) ▪ Agreements – IP, confidentiality & publication agreements & timescales ▪ Manage use of research outputs ▪ Manage meetings & roles – ensure equal contribution ▪ Plan for any changes (e.g. personnel changes, change in objectives, etc.)

Relationship management may not be necessary for participants who already have a successful personal or working relationship but would be useful for 'new' collaborators and for participants who have very different cultures or attitudes, for example, 'traditional' academics and businessmen from small companies.

Management is also shown in the research findings to be important when the motivations and objectives for collaboration are being shared, both prior to setting up the collaboration structure and during the process. Managing the motivations and objectives involves ensuring that all parties understand what each organisation and individual expects from the collaboration and conducting a realistic assessment of what can be done to avoid unrealistic expectations. It also involves looking for ways of balancing the needs of both parties to ensure mutual benefits and this depends on the attitudes of the participants (understanding & willingness). This is an important initial planning stage that ensures that an appropriate collaboration structure is set up. The management approach also needs to be adaptable to be able to deal with any necessary changes in objectives during the collaborative process.

Figure 6.2 shows the revised model, with the three 'elements' added to all three sides of the 'triangle'. One other change to the model is the addition of another dashed arrow to the left side of the model showing that 'outcomes or changes' during the collaborative process could lead to a necessary restructuring of the collaboration (e.g. 'unexpected' commercial benefits, personnel and company changes). The research findings have demonstrated the need for a flexible and adaptable management approach to deal with any changes that could occur during the collaboration process. The fieldwork results also support the other dashed arrow in the model which indicates that the outcomes (e.g. benefits, publications, results, etc.) of collaboration, either positive or negative, can alter participants' attitudes.

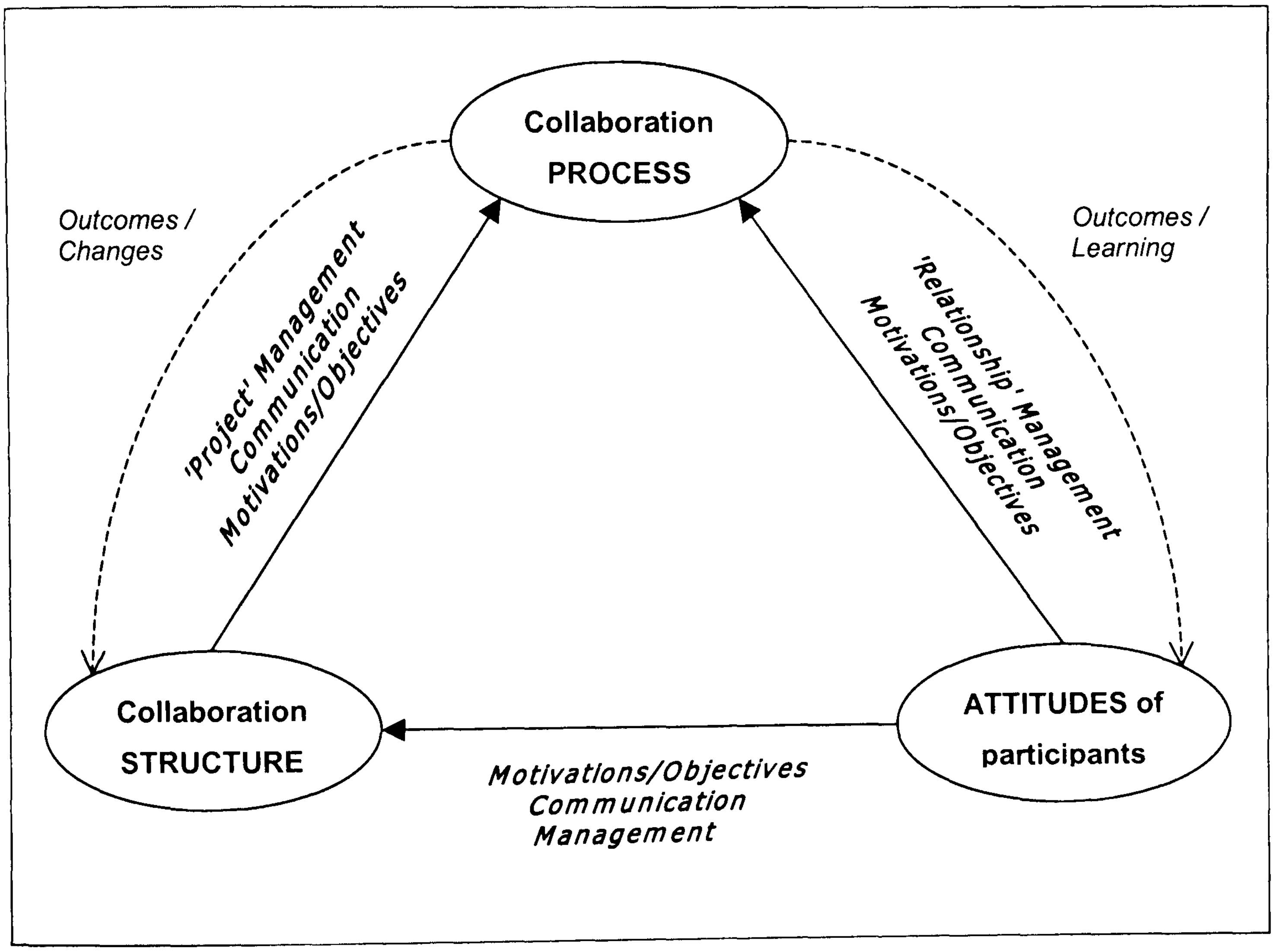

Figure 6.2: Revised conceptual model of Industry-Academia collaboration

6.5 Summary

This chapter has drawn together the results of the fieldwork and reviewed them in terms of how they support or contribute to the existing literature on industry-academia collaboration and to the conceptual model developed in Chapter 3.

The perspectives of the two response groups, the collaborative research facilitators and the students, were also compared. The research findings support the current awareness in the literature that industry-academia research collaborations are difficult to analyse, compare and manage because of their diverse and complex structures, their dynamic nature (i.e. changes over time) and the variety of factors that influence their effectiveness, each of which is not predominant in every case. The results of the student survey will contribute usefully to the literature because no in-depth studies appear to have been carried out to date on the experiences of students involved in industry-academia collaborative projects despite recent concerns about their involvement in such projects. It is clear that such projects need to be carefully managed to be effective, in particular the management of communication between the participants and of industrial placements.

Comparing the responses of the collaborative research facilitators and the students has shown some evidence that individuals who are not involved at the coal face of collaborative research may not be aware of some of the problems that occur during collaboration (e.g. pressures from industry, problems reporting the results). The collaborative research process is also prone to unexpected developments or outcomes, both negative and positive, making it challenging to manage. Also the attitudes of the industrial and academic participants can change over time. This indicates the importance of evaluating collaborative research at different stages of the process, both at the project and at the relationship level. This would help continuous improvement in the process, implementation, and effectiveness of the collaboration.

The research findings have been valuable in enabling us to test and refine the conceptual model which was developed in Chapter 3 based on the research background in Chapter 2. It is clear that no two collaborations are the same in terms of the three collaboration 'characteristics' in the model: collaboration structure, collaboration process and attitudes of collaborative participants, i.e. all three characteristics are individually complex and interactive. This is also the case for the three 'elements' that the research questions are based on:

motivations and objectives, management and communication. These three 'elements' are all dependent on the three collaboration 'characteristics' and also on each other. Because of the variety in the nature of industry-academia collaboration, the model needs to be tested on other types of interaction.

The final chapter in this thesis (Chapter 7) concludes the study by responding directly to the research questions specified in Chapter 3 (Section 3.2), looking at the implications of the research findings for the planning and management of industry-academia collaborative research, reflecting on the research design and suggesting a number of areas for further study.

7. Conclusions

This final chapter looks at how the thesis has contributed to our understanding of the factors that influence the effectiveness of industry-academia collaborative research. First the research questions that guided the activities reported in this thesis will be reviewed and responded to using the knowledge gained from the research findings described in Chapters 4 to 6. The second section presents a reflective evaluation of the research procedure and the model developed in this thesis to help us study, and understand, the complex nature of industry-academia collaboration. The third and final section concludes the thesis by looking at:

- the implications that the research findings have for the planning and management of industry-academia collaborative research;
- additional issues found in the research findings to be of significance to our understanding of industry-academia collaborative research;
- areas for future research.

7.1 *Responding to the research questions*

The research described in this thesis was guided by a primary research question and three secondary research questions which were formulated based on an analysis of the material presented in Chapters 2 and 3 which suggested that the effectiveness of industry-academia collaborative research depends partially on the following three key elements:

- 'Motivations & Objectives' for collaborative research;
- 'Communication' between collaborative partners;
- 'Management' of collaborative processes.

In Chapter 3 it was anticipated that answering the research questions would help us discover ways of balancing the competing objectives and sources of conflict within collaborating teams, identify effective communication formats and provide guidance on the management of industry-academia research collaborations. It is therefore necessary to return to these research questions and directly respond to them using the knowledge gained from the two core research activities described in this thesis.

In the following three sub-sections, the secondary research questions, each of which covers one of the key elements outlined above, are reviewed and responded to. Combining the responses to these three questions will provide the answer to the primary research question which covers all three key elements:

P1 *'What is the nature and extent of influence of barriers to effective industry-academia research collaboration in terms of (i) motivations and objectives, (ii) communication, and (iii) management?'*

7.1.1 Motivations & objectives for collaborative research

S1 *Are there differences in individuals' motivations for or perspectives towards collaboration in different sectors and how do these differences influence the effectiveness of collaboration?*

The research reported in this thesis has revealed a wide variety of motivations for industry-academia collaboration both at the individual and organisational levels. The variation in motivation by type of industrial (e.g. science-based versus craft-based organisations) and academic (e.g. pure versus applied) partner needs to be further analysed, but it is evident that the motivations are related to the individual and organisational cultures of the participants. The motivations are also influenced by external factors such as the decline in funding from government which has driven academics to find other sources of finance and an increasingly competitive market which has forced industry to search for new ideas or knowledge from universities to sustain future profitability. The findings also showed a variety of perspectives towards collaboration which are also related to the different cultures, attitudes and interests of the participants. There is also evidence of external factors influencing the attitudes of the participants, for example, in some universities the RAE appears to reduce the motivation to collaborate with industry.

The research results exposed some evidence that the different motivations and objectives of industrialists and academics are correlated with the effectiveness of collaboration. For example, differences in motivations or objectives can delay negotiations at the start of a collaborative relationship where attempts are being made to try and meet the different needs and expectations of the participants. The findings indicate that in sectors such as the pharmaceutical industry the objectives and working practices of industrialists and academics are quite similar, therefore collaborations are more likely to be successful in such fields. The student survey findings showed that collaborative projects involving pharmaceutical companies encounter fewer problems in relation to differences between the partners, project timescales and communication, compared to those involving water (craft-based) companies.

The diverse motivations of industry and academia should not be criticised because they complement each other in several aspects including knowledge, skills, finances and human and physical resources. The needs of both sides should be balanced to ensure that the two parties achieve mutual benefit from collaboration. Failure to achieve such a balance could lead to low enthusiasm and a subsequently unsatisfactory relationship. Poor clarification of motivations or objectives at the outset can lead to unrealistic expectations and misunderstandings. There is some evidence in the research findings of a lack of awareness regarding why industry wants to collaborate and that the motivations or objectives of the industrial partner can change during the collaboration, which can cause problems where their new motivations or objectives cannot be satisfied.

7.1.2 Communication between collaborative partners

S2 *Do individuals' disciplinary backgrounds influence communication and knowledge transfer between collaborators?*

The research findings showed some evidence of communication problems between industrial and academic collaborative participants as a result of their disciplinary backgrounds. It is evident that organisational (& individual) culture has an important influence on communication and knowledge transfer. The effect of individuals' disciplinary background varies by sector, depending on the nature of the work they do, the type of people they work with and the amount of collaborative experience they have. The results of the student survey confirm that the compatibility of the participants' backgrounds can significantly influence the perceived success of collaboration. As stated in the previous section, there is some evidence that collaborations involving science-based organisations (e.g. pharmaceutical companies) encounter fewer communication problems than those involving craft-based organisations (e.g. water companies), presumably because individuals in science-based companies have similar disciplinary backgrounds to academics. Further research however needs to be carried out to explore how variations in the educational qualifications and professional disciplines (e.g. engineer, manager, scientist, etc.) of industrial and academic participants influence collaboration effectiveness. This could be done by analysing in depth the professional and educational backgrounds of the industrial and academic supervisors in the student survey. Such information would be useful for the management of interdisciplinary collaborations.

Some of the communication problems that emerged in the research findings resulted from differences in the professional languages (or 'jargon') of the participants. Developing a joint language that all the participants can understand takes time. This process depends on the approach taken to overcome language differences for example, regular face-to-face meetings and explanation of jargon by the participants themselves or by a facilitator. It also depends on the participants' abilities and willingness to learn and achieve mutual understanding. Another common cause of ineffective communication and knowledge transfer in collaborations is industry's concern for confidentiality. Some industrial partners do not believe academics can be trusted because of their preference for open communication. There was evidence in the results of the student survey (Chapter 5) of students encountering problems with communicating with their academia supervisor or reporting on their work because of confidentiality issues created by their industrial supervisor.

7.1.3 Management of collaborative processes

S3 *What are appropriate managerial or organisational strategies for effective industry-academia research collaboration?*

It is evident from the research findings that because no two collaborations are the same in terms of motivations, objectives, structure, process, outcomes, type of participants, etc. it is not easy to state what the appropriate management strategies are for effective industry-academia research collaborations. There are however a number of research findings regarding best practice in the management of collaborative research which can be deemed generic. These include having an adaptable management approach because industry-academia collaborative research is prone to unexpected developments, changes and outcomes, particularly if the research is curiosity-driven. Appropriate mechanisms for the establishment or development stages of collaborative research include ensuring that the motivations and objectives for collaboration are clarified between all participants, that there is good communication (i.e. regular meetings) and mutual understanding between the participants, and that agreements are set up to sort out issues such as intellectual property and confidentiality.

The student survey elicited information regarding the management of collaborative projects involving students (EngD & CASE projects). The collaborative research facilitator survey obtained some information on the management of other types of collaboration, for example, large-scale collaborations and collaborative networks, but more in-depth analysis (i.e. analysis at the coal face) is needed to explore appropriate management structures for such collaborations. Concerning collaboration agreements, many respondents in the student survey were uncertain whether there was one set up for their projects as they are not involved in the planning stages. Also in the case of the research councils, they pass the responsibility for setting up agreements on to the universities. Thus more information is required from the industrial and academic partners themselves to explore in detail the problems that are encountered with setting up agreements to find appropriate solutions.

The results also revealed the importance of 'relationship management', particularly when seeking a successful long-term collaborative relationship. Relationship management is recommended in collaborations which involve participants with very different disciplinary or cultural backgrounds. It would help resolve attitudinal related problems and ensure that there is mutual understanding between all the participants. This approach would in turn aid the development of mutual trust and good personal relationships between the participants. It could either be done by a third party, with understanding of both industrial and academic cultures, languages and working practices, or by champion(s) within the participating organisations. The role of facilitators or relationship managers in collaborations however needs to be explored further by analysing collaborations that involve such individuals.

7.2 Reflections on research design

The objective of this thesis was to explore and gain greater understanding of the factors that influence the effectiveness of industry-academia collaborative research. It was evident from the literature review (Chapter 2) that this is a very complicated topic to study because of the wide range of factors involved and also the variety of perspectives on what constitutes successful collaboration. As shown in the previous section, the research in this thesis has been successful in answering the research questions and improving our understanding of the importance of the three key elements: motivations, management and communication for the effectiveness of industry-academia collaboration. There have, however, been a number of limitations in the research procedure used.

The next two sub-sections assess the usefulness of the research methods developed and used in this thesis. The first sub-section looks at the value of the model developed which, in addition to the research questions (see previous section), helped direct the research activities described in Chapters 4 and 5. The model was first presented in Chapter 3 (Figure 3.1) where it was derived from knowledge gained from the material presented in Chapter 2. It was revised in Chapter 6 (Figure 6.2) as a result of the fieldwork undertaken (Chapters 4 & 5). The second sub-section looks at the methods used to analyse the perceptions of individuals involved in industry-academia collaborative research.

7.2.1 Model for exploring industry-academia collaboration

As there was no suitable conceptual model in the literature relevant for the study reported in this thesis, a model was developed to depict the complicated nature of industry-academia relationships and to illustrate the importance of the three key 'elements' (motivations/objectives, management & communication) for the effectiveness of industry-academia collaboration. It describes the relationship of these three 'elements' to three collaboration 'characteristics' (structure, process & attitudes of participants). Using the model has enabled much to be learnt about industry-academia collaborative research by directing us to explore all three collaboration 'characteristics' and three 'elements' during the two core research activities (Chapters 4 & 5). As a result of this exploration and our greater understanding of the nature of collaborative research, the model was revised (in Chapter 6) to improve its appropriateness for representing industry-academia collaborative research.

The model has enabled us to see and understand the multifaceted nature of industry-academia collaboration by showing us that within the model all three 'elements' are individually complicated and interactive, and that their effects are interdependent. It is a useful framework showing why it is important to explore each of the three collaboration 'characteristics' (and also each of the three 'elements') when identifying factors influencing the efficiency of a collaborative relationship. This in turn helps us find ways of improving the collaboration's effectiveness by setting up the right 'elements' according to the collaboration's 'characteristics'. For example, if the participants have very different attitudes, relationship management may help reduce cultural related conflicts and if the collaboration involves a student, the project manager should set up procedures to protect the student's academic rights, etc. during collaboration. This indicates the model's value as a framework for planning and managing industry-academia collaborations by ensuring that participants take into account and understand the importance of all three 'elements' and three 'characteristics' within the model.

It is acknowledged that because there are a variety of types of collaboration with different structures and processes, the model will need to be tested for its suitability for analysing other forms of collaboration between industry and academia. It may need to be adapted to be appropriate for exploring and understanding particular forms of collaboration. This model could also be used as a comparative tool for differentiating between different types of collaboration and also collaborations in different fields of research or industrial sectors. The research findings have showed that in some research fields or industrial sectors, collaborations can be more problematic that in other areas because of a range of factors including differences in organisational cultures or attitudes, inappropriate funding support (from the government) and differences in the types of research outcomes.

The model also suggests a number of ideas and areas for future research; for example, in-depth exploration of the importance of the relationship between specific elements in the model for the effectiveness of collaboration such as that between individual or organisational cultures and 'learning by doing' collaboration within different research or industrial sectors. There is some evidence in the literature that the learning process varies between different organisations (e.g. SMEs have a limited ability to learn; Stewart, 1999; Dodgson, 2001) and therefore extra support or time may be needed to achieve a more successful collaboration. To further enhance our understanding of the multifaceted nature of industry-academia collaborative research, future activities could involve:

- encompassing the views of the industrial and academic supervisors in CASE and EngD projects, and comparing the results with those of the student survey which would be a time consuming task but would provide a more complete picture and could provide additional insights;
- analysing the perspectives of collaborative network participants and comparing these with the theoretical views of the collaborative research facilitators;
- using the conceptual model as a comparative tool to distinguish between different types of collaboration and collaborations in different sectors;
- a study of long term strategic relationships which are believed to be more successful because they allow the development of good personal relationships and trust because of the greater timescale;
- further analysing the complex relationship between individual/organisational culture and 'learning by doing' collaboration.

7.2.2 Analysing individual perspectives on industry-academia collaboration

The two fieldwork activities in this thesis were designed with the general objective of eliciting the reflections and perceptions of individuals of their experience of industry-academia collaborative research. Prior to carrying out the studies, it was evident from the literature review (Chapter 2) that exploring individuals' perceptions on industry-academia collaboration would be very difficult due to differences in individuals' beliefs about what constitutes success or failure in collaborative research. Both the interview survey (Chapter 4) and the questionnaire survey (Chapter 5) were successful in obtaining the perspectives of the collaborative research facilitators and the students. Both response groups were very willing and able to reflect on their beliefs or experiences of industry-academia collaboration. Obtaining the respondents' reflections on what was intended to happen and what has happened (or is happening) over time enabled us to gain greater understanding of the dynamic nature of the collaborative research process and structure. Comparing the responses of the research facilitators and the students, even within each response group, revealed some interesting differences in relation to the nature of their experience of collaborative research.

Obtaining the students' reflections on their collaborative research projects saved a considerable amount of time and resources by allowing us to see the success of their projects from their perspective and from those of the industrial and academic participants. Combining the results of both research activities provided a great wealth of material on the topic and this information has helped us answer the research questions (Section 7.1) and also refine the model which was based on understanding from the literature review (Chapter 6.4.1). The model may now be applied to further studies of industry-academia collaborative research, and perhaps other forms of collaboration, to advance our understanding of such collaborations.

7.3 *Final conclusions*

The main aim of this study was to identify and enhance our understanding of the factors that influence the effectiveness of industry-academia collaborative research, which is an increasingly important area of public policy. The following activities have been carried out as part of this study:

- a review of the current literature on industry-academia collaboration (Chapter 2) enabled the development of the research questions and a conceptual model to help guide the research agenda (Chapter 3).
- two core fieldwork activities were carried out to obtain and analyse the perspectives of individuals involved in industry-academia collaborative research: an interview survey of collaborative research facilitators (Chapter 4) and a questionnaire survey of students involved in collaborative projects (Chapter 5).
- the results of the two surveys were integrated in Chapter 6 and led to the revision of the conceptual model originally developed in Chapter 3. The findings also enabled us to directly respond to the research questions developed in Chapter 3 (Chapter 7.1).

This study has both deepened and broadened our understanding of the nature of industry-academia collaborative research, in particular in terms of how the participants' motivations and objectives for collaboration, communication between the participants and collaboration management approaches are associated with perceived collaboration effectiveness. It has shown us the characteristics of unsuccessful and successful collaboration, and improved our awareness of the sources of tension. It has also demonstrated how both qualitative and quantitative measures can be used to evaluate industry-academia collaboration.

The findings of this thesis however present a number of implications for the planning and management of industry-academia collaboration. The results emphasised the complex nature of industry-academia collaborations by showing that their efficiency can be influenced by a wide variety of factors related to the attitudes of the participants, and the collaboration's structure and process. It is evident that no two collaborations are the same in terms of these three issues and therefore the factors causing ineffective collaboration may vary greatly between each case. The dynamic nature of collaborative research in terms of changes over time and unexpected outcomes also makes such collaborations challenging to manage. The conceptual model developed in this thesis however provides a good foundation for understanding the various complex issues and identifying potential sources of problems in industry-academia collaboration.

In relation to the future of industry-academia collaborative research, the evidence indicates that future collaborations may become more successful because of growing mutual understanding and awareness between industry and academia, and also due to an increase in collaborative experience. Changes in individual and organisational attitudes or cultures resulting from increased collaboration may however create serious problems in the future. There is evidence that some academics are becoming more business focused and paced as a result of collaborating with industry. Learning from collaboration brings about changes in awareness, understanding, behaviour and beliefs, and there is a risk that learning from each other can lead to the participants (individual/organisational) becoming more similar in their ideas and ways (Dodgson, 2001). This could result in a reduction in the quality of academic research and also in novel insights, which could create problems for innovation. Measures therefore need to be taken to ensure that the basic missions or working practices of the participants are not altered. Collaborative schemes like CASE are shown to be valuable here in that they take into account both basic and applied research, and support quality research over more flexible and longer timescales.

Concerning the role of the UK government (Research Councils), it is evident that government constraints on funding and recent government policy statements are a major driving force for industry-academia collaboration. There is evidence that government schemes for collaborative research are improving and becoming more realistic, mainly because they are learning from experience or by observation. There are however, some indications of a lack of support from the government in particular with regard to how to set up collaboration agreements and some schemes are shown to be inappropriate for some sectors such as the social sciences and for small and medium sized enterprises (SMEs). The challenge for the government is therefore to recognise the needs of individual actors and thus provide more tailored support for what is an activity of significant benefit to all parties.

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APPENDICES

List of Appendices

APPENDIX 2A: Bibliometric Study

1. Introduction

The objective of the study described here is to depict and explore the significance of research collaboration within a specialist field of research in terms of trends over time (dynamics) and disciplinarity (structure). The method used to achieve this is a bibliometric analysis of co-authored scientific publications. The particular field that was analysed is the field of membrane applications for water treatment which is a speciality in the water industry that is characterised by both strong science and strong application oriented research, i.e. it is an applied, not pure science area. This field is a good example of a multidisciplinary environment where a wide range of subject disciplines and scientific, technological and industrial domains are involved. Research and new technologies in this field are increasingly important due to the increasing stringency of water quality guidelines and standards being introduced for municipal water treatment (Judd & Jefferson, 2003).

The study described here provides three central functions; it is:

- Descriptive, in that it introduces us to the extent and nature of industry-academia collaboration;
- Analytical, in that it manipulates the data to characterise trends in collaboration over time;
- Anticipatory, in that it provides a body of knowledge, which complements the information obtained from the literature on various aspects of industry-academia collaboration (Chapter 2).

Exploring how the nature and extent of research collaboration has changed over time enables us to further enhance our understanding of the various factors that influence the increasing level and complexity (in terms of disciplinarity) of research collaboration between industrialists and academics. First some background on the use of bibliometric techniques for evaluating collaborative trends is presented, then the methodology and results of the activity carried out are discussed with reference to similar studies in the literature. This bibliometric study has also been published in: Butcher, J. & Jeffrey, P. (2004). Using bibliometric indicators to explore industry-academia collaboration trends over time in the field of membrane use for water treatment. *Technovation*,

2. Using bibliometrics to study patterns of and trends in research collaboration

Industry-academia interactions can result in a variety of types of output including new technologies, techniques, instrumentation, methodologies, prototypes, and patents. Collaboration may also produce co-authored papers. Due to the variety of activities and outputs, no single measure is fully able to capture the complete range of industry-academia collaborations (Calvert & Patel, 2002). Jointly authored scientific papers reflect collaborative research and are one indicator of links between researchers in industry and universities (Hicks & Katz, 1996). When producing such papers, researchers exchange tacit and embodied elements of knowledge. There have been several studies in the past that have explored or measured research collaboration using bibliometric indicators such as 'co-authorship' which entails multiple-author or multiple-address publications, or 'citations' which are references in papers that indicate use of research by others (e.g. Qin, 1994; Hicks *et al.*, 1996; Tijssen & Korevaar, 1997; Rao & Raghavan, 2003). The use of bibliometrics has been shown to be very useful in studying research intensive innovation systems by enabling the identification of prominent actors in public and private sectors and their scientific profile as well as relations between them, and in illustrating the extent of international collaboration (Sandstrom *et al.*, 2000).

Various simple measures of collaboration have been employed in the literature including the mean number of authors per paper and the proportion of single and multi-authored papers. Cross-sectoral and cross-disciplinary collaboration can also be explored by looking at the institutional and disciplinary affiliations of authors which may be obtained from their correspondence addresses in scientific publications. Bibliometric indicators provide information on a country's publishing rate, the degree to which their researchers collaborate internationally and changes in collaborative patterns over time. There have however been very few studies that have looked specifically at industry-academia collaboration patterns. For example, Calvert and Patel (2002) state that despite increasing interest amongst policy makers and others, there have been few attempts at gathering systematic data on the nature and extent of research collaborations between universities and industry.

Although there are several advantages to evaluating collaboration through bibliometrics, including the public availability of the information, there are some drawbacks to the use of this method, as has been pointed out by several authors in the literature. For example, Katz and Martin (1997) explain in detail why co-authorship can never be more than a rather imperfect or partial indicator of research collaboration between individuals, and Tijssen (1998) states that co-authored research papers listing both a university and a firm are inadequate in reflecting the nature and intensity of public-private linkages. Numerous collaborations do not result in a published paper signed by several institutions, thus they cannot be detected by co-authorship based indicators (Martin-Sempere *et al.*, 2002). There are also a number of cases where co-authorship may occur without a substantial degree of research collaboration (Calvert & Patel, 2002). Also bibliometric data cannot tell us about the nature and format of a relationship between collaborators, the factors that influence the initiation and ongoing process of collaborative research, how scientists communicated the information, etc. (Qin *et al.*, 1997).

3. Bibliometric study: method

The Cambridge Scientific Abstracts Internet Database Service (www.csa.com) was used to retrieve papers containing the keywords 'membrane' and 'water' from 8 scientific journals that publish research articles on the application of membranes to water treatment. Three experts were asked to name top journals in the field; the identified set of journals for this study comprised: Aqua (*IWA Publishing*), Desalination (*Elsevier*), Environmental Technology (*Selper Ltd*), Filtration & Separation (*Elsevier*), Journal of the American Water Works Association (*AWWA Publication*), Journal of Membrane Science (*Elsevier*), Water Research (*IWA Publishing/Elsevier*), and Water Science & Technology (*IWA Publishing*). The database search retrieved 1678 papers from the years 1967 to 2001.

The following variables were retrieved from the authors' correspondence addresses: institutional affiliation according to type of institution (academic, non-academic research, industry, or government), disciplinary affiliation (subject field of department or industry sector) and nationality (country). A very large number of subject fields were obtained from the authors' disciplinary affiliations, reflecting the interdisciplinary nature of membrane science and technology (and possibly also the increasing specialism of university research departments). A classification scheme was therefore created for all the subjects to facilitate coding of the authors' disciplinary affiliations (see Annex 1). All data were entered into SPSS (Statistical Package for the Social Sciences) for analysis. Calculating the number of different authors, institutions and countries in each paper enables us to explore changes in patterns of collaboration over time using the following measures:

- the proportion of single and co-authored (collaborative) papers;
- the proportion of papers corresponding to three different types of collaboration: i) intra-departmental, ii) inter-institutional, and iii) international;
- the proportion of interdisciplinary papers, i.e. those involving two or more unique subject disciplinary affiliations;
- the proportion of academic-industry (non-academic) collaborative papers.

The results of the data analysis are presented in the following section. It should also be noted that in addition to the generic issues listed above, there are some specific limitations of the bibliometric measures used here, these include:

- not all the authors associated with a particular paper may have actually worked together, especially in papers where there is a large number of authors.
- there may be some inaccuracy in the classification of the subject affiliation of some authors as some may not correspond with the author's actual specialisation (e.g. some addresses only provide the name of the organisation, not the specific department that the author works in. Also, departmental names may not accurately reflect researcher backgrounds).

Therefore the results only present an approximate picture of the extent and interdisciplinarity of research collaboration patterns in the studied field. Despite this limitation, the data will nevertheless provide us with a useful overview of the development in both industry-academia and interdisciplinary collaboration patterns. Using information from the literature, the various factors that influenced the changes in both the extent and nature of collaboration (in terms of disciplinary structure, both institutional and subject) over time will be discussed.

4. Bibliometric study: results

4.1 Co-authorship trends

By calculating the number of authors in each paper and therefore the number of single and co-authored papers for the last 35 years (1967-2001), it was revealed that of all the papers (1678), only 13% were single-authored and the rest (87%) were co-authored papers (i.e. involved two or more authors). This indicates that the field of membrane science applications to water treatment is a highly collaborative area of research. Figure 1 shows the number and percentage of co-authored (collaborative) papers over the 35 year period (grouped into five-year ranges). There was a large increase in the number of collaborative papers over the period investigated, with the largest increase occurring over the last 15 years. The proportion of papers that are collaborative for each five-year period increased from 57% in 1967-1971 to 90% for the last 5 years (1997-2001). In general terms, the increase in the number of papers demonstrates the growth in the field of membrane use for water treatment over time. The field began as a research 'speciality' in the 1960s and its rate of growth was slowest during the early stages (1967 to early 1980s) and fastest during the last decade as it has matured.

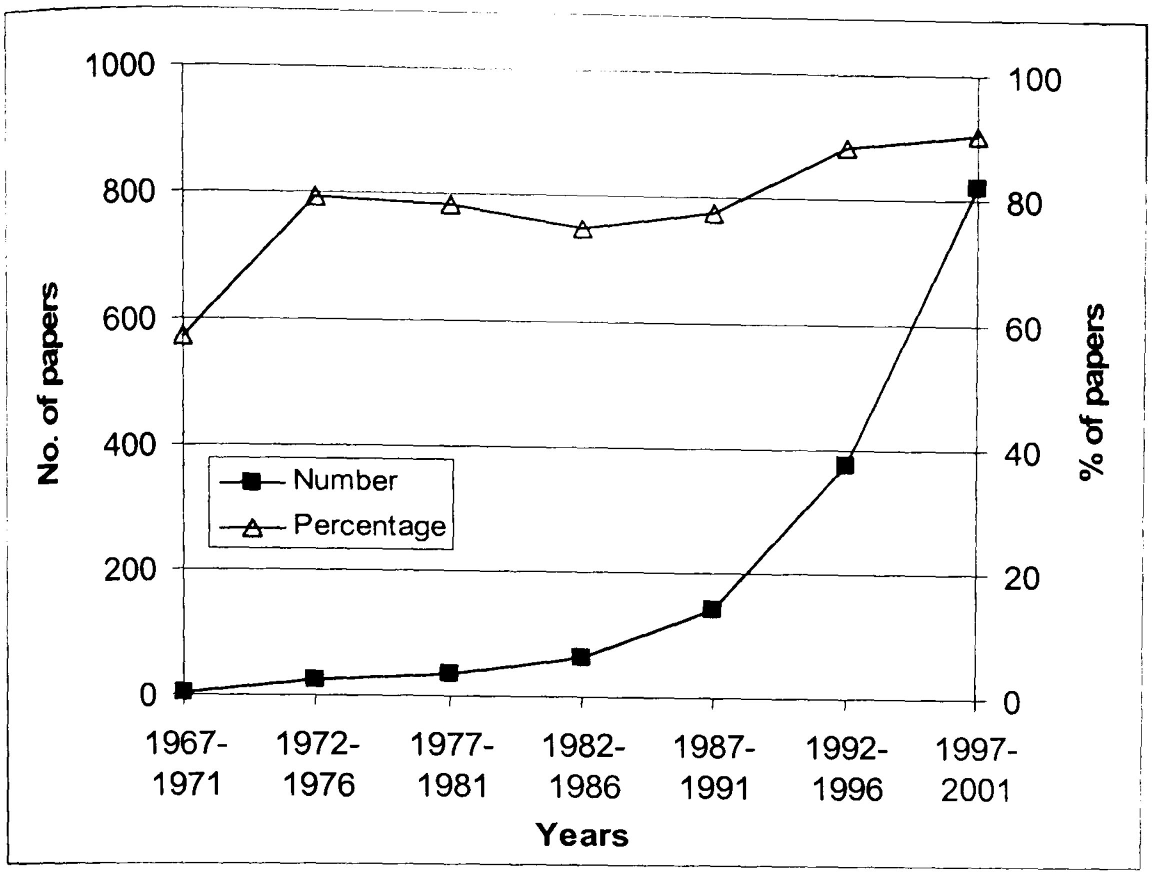

Figure 1: Trends in the number & percentage of collaborative papers

There are various other professional, economic, social and political factors that influence research collaboration trends. Katz and Martin (1997) show six main factors for the increasing level of research collaboration over the last few decades: (i) increasing costs of conducting fundamental science at the research frontier; (ii) substantial fall (in real terms) in travel and communication costs; (iii) science is a social institution where advances depend crucially on interactions with other scientists; (iv) increasing need for specialisation within certain scientific fields, especially those where the instrumentation required is very complex; (v) growing importance of interdisciplinary fields, as some of the most significant scientific advances come about from the integration or 'fusion' of previously separate fields; and (vi) various political factors encouraging greater levels of collaboration among researchers. Another factor not included in this list is changing institutional cultures and attitudes (Stewart, 1999).

Figure 2 illustrates trends in the percentage of papers by number of authors. An interesting feature here is the decrease in the proportions of single and two-authored papers over the past 35 years, while the proportions of four and five or more authored papers have increased. The single author papers were most common in 1967-1971 but least common by 1997-2001. Calculating the mean number of authors per paper reveals an increase from 2.78 authors per paper in 1972-1976 to 3.57 authors per paper for 1997-2001.

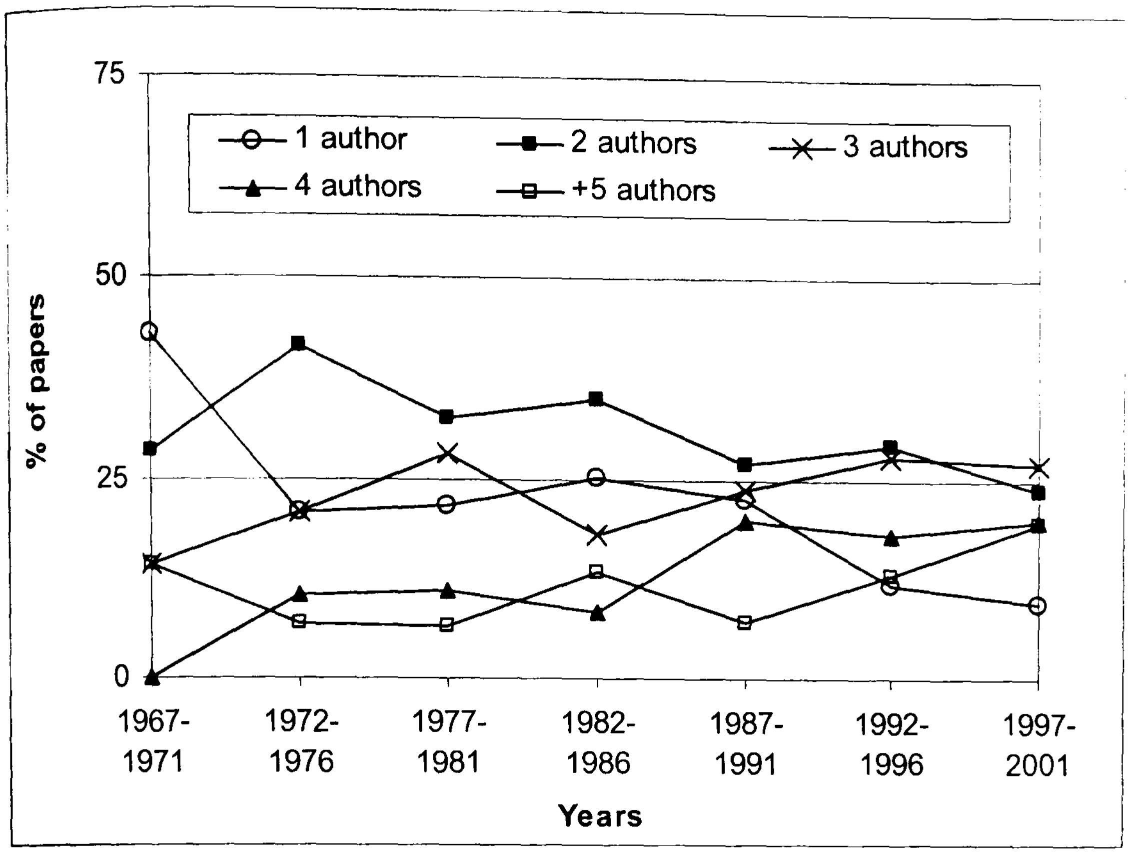

Figure 2: Trends in the percentage of papers by number of authors

The increase in the number of papers authored by large groups (> 4 authors) suggests that larger collaborative groups have gradually become more common, or perhaps more successful, in a mature field of research such as membrane applications to water treatment. These findings support the evidence for similar trends in co-authorship patterns observed in the literature. For example, Hicks and Katz (2000) found an increase in the proportion of papers with four or more authors and a decline in the share of papers with one or two-authors in their study of collaboration trends in the UK from 1981 to 1994. The trend was explained as the result of a change in the breadth of resources (skills, equipment & material) required to produce a piece of knowledge (i.e. more people with different resources are needed).

4.2 Institutional collaboration trends

Analysing the authors' disciplinary affiliations showed that of all the papers published during the 35 year period, 43% involved collaboration between two or more different institutions (or different departments within one institution) and 12% involved international collaboration (between two or more countries). Figure 3 shows the trends in the percentage of collaborative papers corresponding to three different types of collaboration: i) intra-institutional (where all authors in the paper come from the same institution), ii) inter-institutional collaboration, and iii) international collaboration.

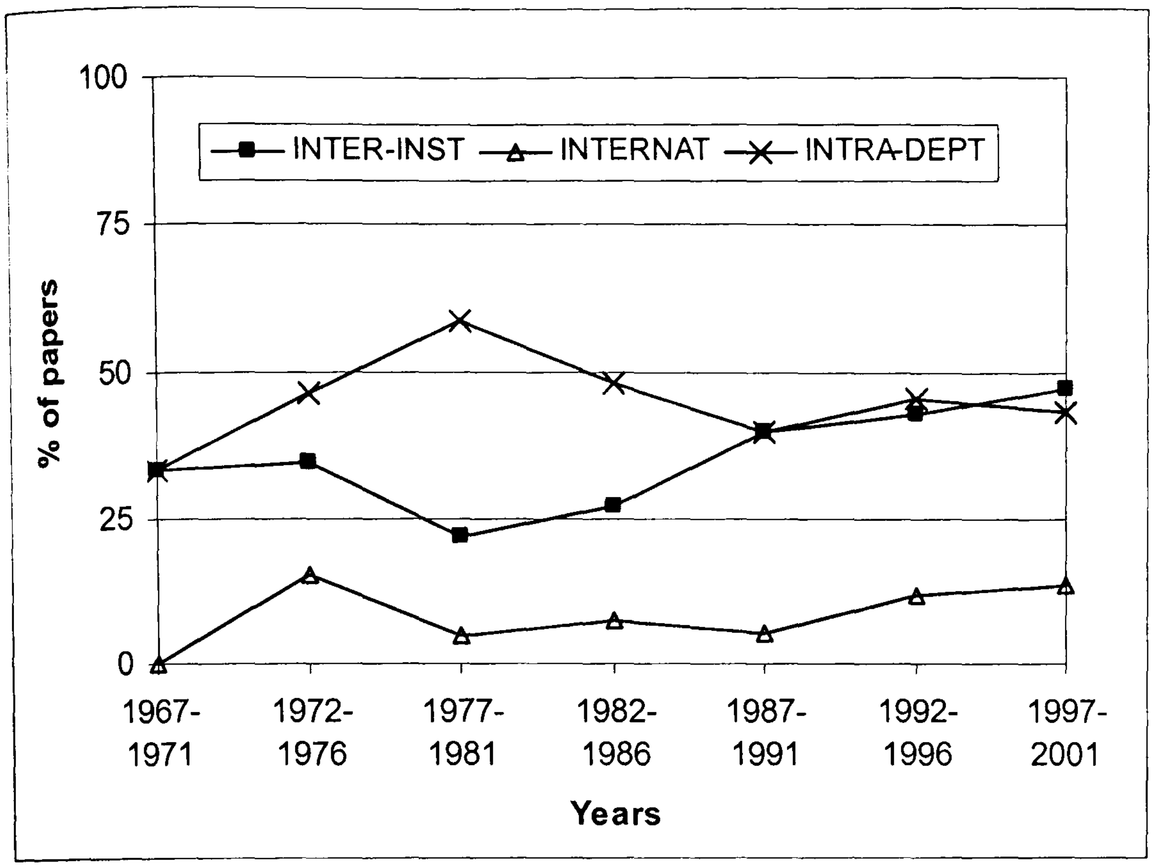

Figure 3: Trends in the percentage of papers by three types of collaboration

Ignoring the data points for the first 10 years which may be biased due to the relatively low number of papers in those years; the proportion of papers involving inter-institutional collaboration increased from 1977 onwards, overtaking the proportion of those involving intra-departmental collaboration over the last five years. In their study, Hicks and Katz (1996) also observed an increase in the number of papers published by authors working at more than one institution during the 1980s (from 28% in 1981 to 41% in 1991). These trends suggest that because resources located at one institution are becoming less sufficient to produce knowledge; researchers from different institutions increasingly collaborate to combine different resources to support research. Figure 3 also shows an increase in the proportion of papers involving international collaboration from 1987 onwards. Several factors contribute to increasing international collaboration but according to Hicks and Katz the most important factor is cheaper travel and communication. International collaboration is significant as it allows the transfer of knowledge and expertise between countries and helps increase the process of integration.

4.3 Cross-disciplinary collaboration trends

Figure 4 shows the trend in the proportion of interdisciplinary collaborative papers (i.e. involving two or more unique subject disciplinary affiliations). Of all the papers, 35% involved two or more unique author disciplinary affiliations. A gradual trend towards interdisciplinarity can be seen by observing the increase in the proportion of papers that are interdisciplinary from 1977 onwards (again ignoring the earlier data points due to the relatively low number of papers). This suggests that as the field becomes more mature there is a greater need for cross-disciplinary collaboration due to the increasing complexity of research problems in the area and the need to 'knit together' knowledges to provide applied outcomes.

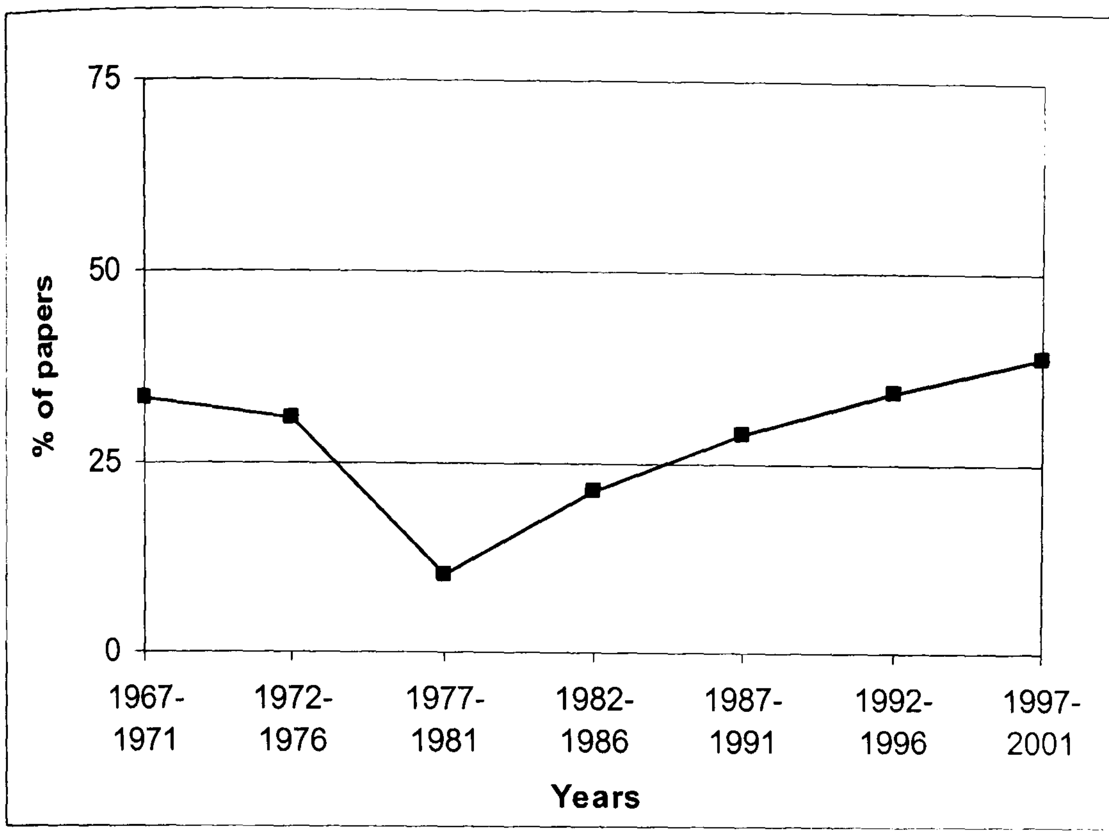

Figure 4: Trend in the percentage of interdisciplinary collaboration papers

4.4 Industry-Academic collaboration trends

Of all the papers analysed, 18% involved collaboration between academics and industrialists (non-academics). As illustrated in Figure 5, there was an increase in the proportion of industry-academic collaborative papers from 1982 onwards (again ignoring the first two data points). This is when the biggest increase in the number of papers occurred (as shown in Figure 1) and therefore indicates that such collaboration was a crucial element in the development of the field. A significant proportion (91%) of industry-academic collaborative papers were interdisciplinary and a quarter of the papers involved international collaboration. The mean number of authors per industry-academic paper was 3.00 in 1972-1976 and increased to 4.49 authors per paper in 1997-2001.

There is also evidence in the literature that the level of industry-academia research collaboration has been increasing over the last 20 years (e.g. Katz & Martin, 1997, Calvert & Patel, 2002). In their study which also used joint scientific publications to measure university-industry collaborations in the UK over the last 20 years, Calvert and Patel (2002) observed an increase in the volume of such collaborations since the 1980s and stated that the biggest increases occurred before the major government policy measures of the mid-1990s (e.g. Government White paper 1993 – HMSO, 1993). They believe that a more important factor was the growing need on the part of firms to collaborate with leading edge academic research in an increasing number of new fields of technological opportunity. There is evidence that many new forms of collaboration between universities and industry came about during the 1980s as a result of the recession which led to major shifts and changes in university-industry relations as traditional approaches were found insufficient (OECD, 1984). During the 1980s science came to be seen as an activity that needed to be more closely linked to technology with a view to improving economic competitiveness (Calvert & Patel, 2002). Also, according to Meyer-Krahmer and Schmoch (1998), the exchange of knowledge is an important motive that has led to a considerable growth of university-industry interaction in recent years.

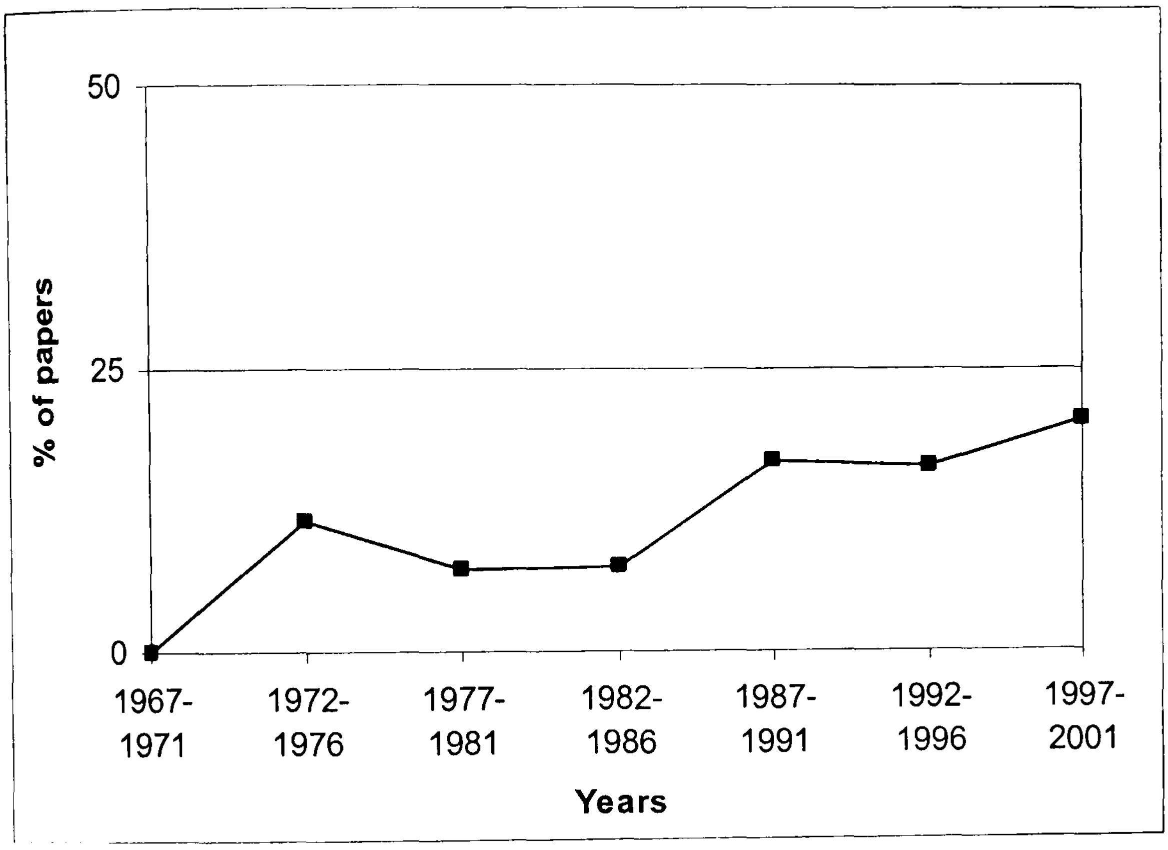

Figure 5: Trend in the percentage of industry-academic collaboration papers

4.5 Comparisons between countries

Differences in the collaboration patterns between different countries were also explored. Historical development, cultural and social attitudes, political decisions and objectives, institutional settings and economic specialisation and structures result in country-specific patterns of industry-science relations (Polt *et al.*, 2001). In 1967-1971 authors from just five different countries published a paper in the field of membrane applications to water treatment but in 1997-2001 authors from 61 different countries published a paper. Table 1 shows the number of papers that involved authors from the UK, USA, Japan and France over the 35 year period.

Table 1: No. of papers involving authors from UK, USA, Japan & France

Year	UK	USA	Japan	France
1967-1971	1	2	0	0
1972-1976	3	16	1	0
1977-1981	6	11	4	2
1982-1986	6	21	7	6
1987-1991	10	32	21	11
1992-1996	41	85	69	36
1997-2001	62	140	92	94
Total	129	307	194	149

The UK has the lowest number of papers published in the field compared to the three other countries. The numbers of 'UK', 'USA', 'Japan', and 'France' papers that involved international and industry-academia collaboration (for each five year period) are illustrated in Figures 6 and 7 respectively. France has the highest proportion of papers that involved international (38%) and industry-academic (37%) collaboration. The UK has the lowest proportion (12%) of industry-academic collaborative papers and there was no evidence of international collaboration until 1992. On the other hand university-industry research collaboration has a longer history in the USA where government incentive schemes for industry-academia collaboration started several decades ago (GUIRR, 1999).

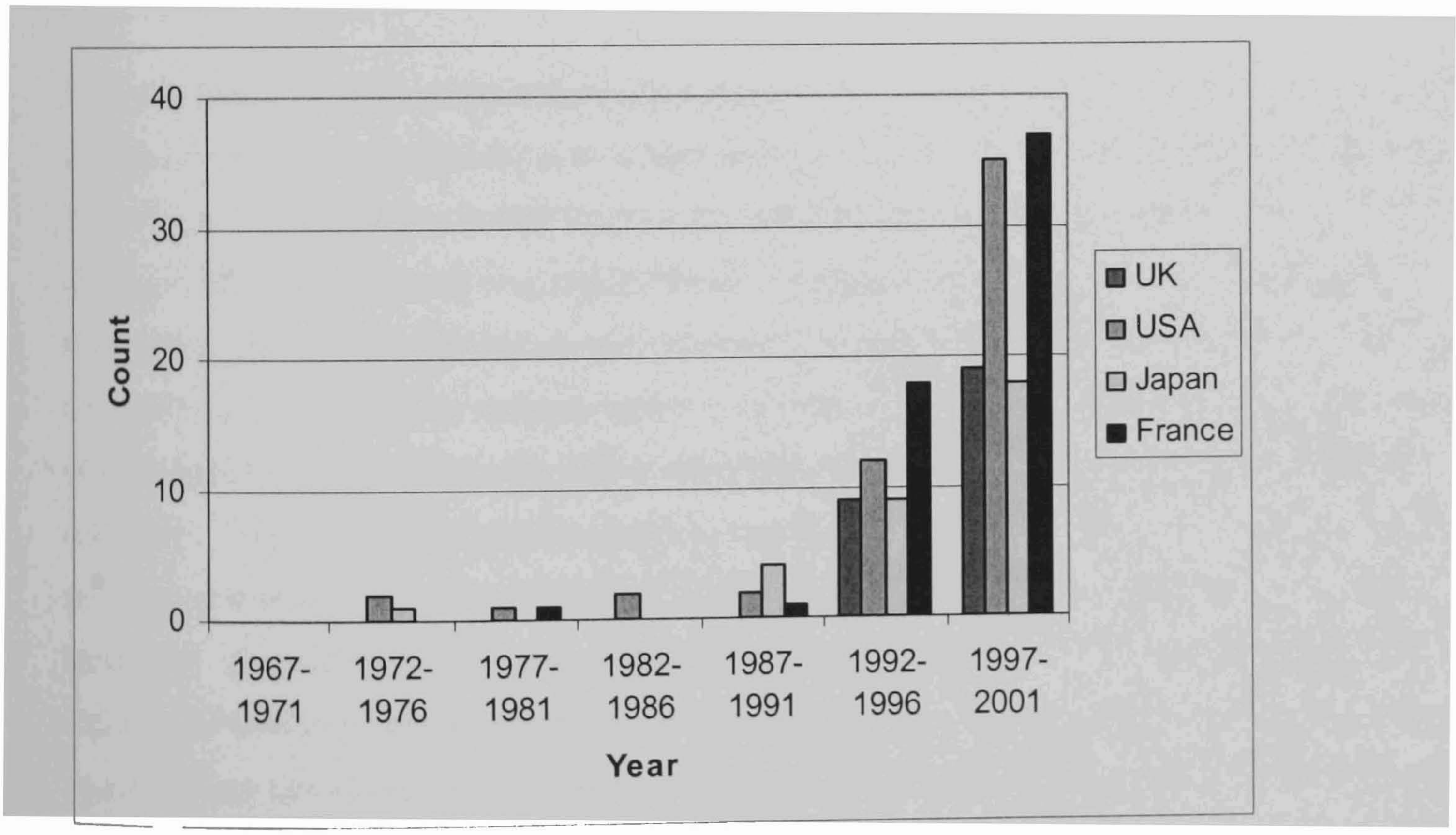

Figure 6: No. of papers involving international collaboration by country

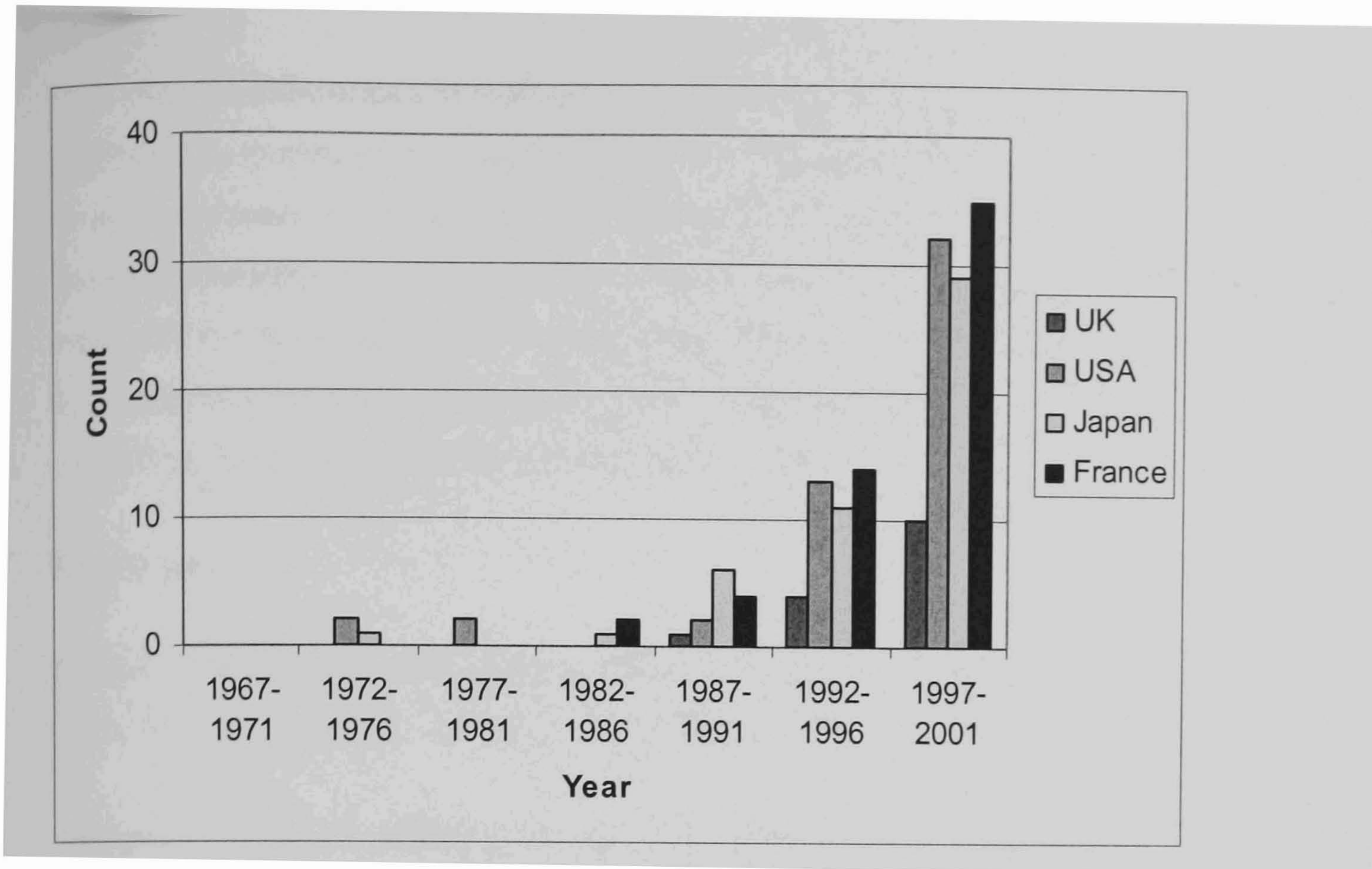

Figure 7: No. of papers involving industry-academic collaboration by country

5. Conclusions

In conclusion, the bibliometric study has shown us the significance of different modes of collaboration in an applied area of research such as the field of membrane use for water treatment. It has demonstrated increasing collaboration between departments, disciplines (subject) and countries as a specialist field of research matures over time. As well as illustrating changes in the nature and extent of research collaboration over time, this study has revealed some of the various factors that may have contributed to the increasing levels of both industry-academia and interdisciplinary research collaboration over the last few decades. Research collaboration between authors, disciplines and institutions is however not new and is very much prevalent in many areas of research, particularly in the "hard sciences", applied sciences and engineering (Rao & Raghavan, 2003). In general terms, the observed trends in inter-institutional, cross-disciplinary (subject fields) and industry-academia collaboration (as shown in Figures 3, 4 and 5) demonstrate the transition from 'mode 1' to 'mode 2' knowledge production as described by Gibbons *et al.* (1994), i.e. transdisciplinarity has become the 'norm'.

It must be remembered that the nature of linkages are sector- and field-specific as the nature of knowledge is different within different disciplinary fields and there is considerable diversity in the approaches taken in different fields (Becher & Trowler, 2001; GUIRR, 1999). This therefore indicates the need to analyse variations in the characteristics of industry-academia research collaboration between different fields of research or industrial sectors because there may be differences in motivations, objectives, barriers to collaboration, management approaches, modes of communication, etc. in different fields. The knowledge gained in this study complements that gained from the literature review (Chapter 2) which reported on current knowledge on other aspects of industry-academia collaboration. While this study has enhanced our knowledge of the complicated nature of industry-academia relationships, it has also presented a number of questions and issues that need to be explored further, supporting the development of the research framework described in Chapter 3.

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Annex 1: Field Classification Codes for Membrane Bibliometric Database

(Adapted from National Science Foundation Science & Engineering Field Classification [http://www.nsf.gov/sbe/srs/rdexp/glossary/s_efield.htm])

Engineering/ Technology

ET1	**Chemical & Process Engineering/ Technology** *(Chemical industry/ services)*	Chemical engineering/ technology; Chemical processes; Process engineering/ technology; Chemical process engineering/ technology; Petroleum science & engineering; Polymer engineering; Pulp/ Paper technology; Separation processes (liquid & solid) technology. Services – Petrol/oil/gas supply/ services. Manufacturing (& R&D) – chemical products/ plants; Separation systems & products (chemicals); Pulp/ Paper; Polymers (biopolymers); Polymer chemicals.
ET2	**Civil & Environmental Engineering/ Technology** *(Industry/ services)*	Civil engineering; Environmental engineering/ technology; Environmental processes; Architecture/ Built environment; Architectural engineering; Environmental Health science & engineering; Environmental protection engineering; Environmental Hygiene; Sanitary engineering; Structural/ Infrastructural engineering; Surveying engineering; Urban engineering; Hydraulic engineering; Waste management engineering. Services – Civil Engineering/ Environmental engineering consultancy; Environmental consultancy/ services; Environmental Sanitation; Waste treatment. Manufacturing (& R&D) - Environmental systems; Sanitary equipment; Fluid (control) systems.
ET2a	**Water & Wastewater engineering/ technology (sub-discipline)** *(Water industry/ services)*	Water engineering/ technology; Water resources engineering, Water treatment engineering/ technology; Water treatment processes technology, e.g. desalination, filtration, separation, purification; Water supply/ utility engineering; Wastewater/ Sewage (treatment) engineering & technology. Services – General water services (inc. consultancy); water supply & water treatment - utilities & waterworks; water treatment plant; wastewater/ sewage treatment; Desalination & Sewage (treatment) plants/ works, Desalination consultancy, Water recycling. Manufacturing (& R&D) - water & wastewater systems; water & wastewater treatment systems; water treatment products (e.g. filters); filtration, separation & purification systems; desalination equipment/ systems; water analytical sensors.
ET3	**Electrical, Energy & Mechanical Engineering/ Technology** *(Industry/ services)*	Electrical/ Electronics engineering; Energy engineering/ technology; Renewable energies (e.g. solar energy, hydrogen); Mechanical engineering, engineering/ applied Mechanics; Computer engineering; Power engineering, Automation, Automatic control, Thermal (process) engineering, Technical thermodynamics. Electrochemical systems Services - Energy/ Electricity supply & services – utilities; Manufacturing (& R&D) - Electrical/ Electronic systems, products & materials (e.g. semiconductors); Energy systems, energy recovery systems, energy conservation technologies, renewable energy systems; Machinery

ET4	**Agricultural & Life Engineering/ Technology** *(Industry/ services)*	Agricultural engineering/ technology; Agricultural bioprocesses; Bioengineering/ Biological engineering; Biotechnology; Biomedical engineering; Biochemical engineering; Food engineering/ technology; Food hygiene; Biofilm engineering; Biosystems; Ecological engineering; Resources & Life engineering. Food industry; Manufacturing – Agricultural chemicals; fertilisers; crop protection products; Bioscience/ Pharmaceutical; Ecological systems.
ET5	**Materials Engineering/ Technology** *(Industry/ services)*	Materials engineering; Materials science & technology; Textile/ Fibres science & engineering; Ceramic science & engineering; Geological engineering; Geotechnical engineering; Mining & Mineral engineering; Metallurgical engineering; Metallurgy/ Metallogeny. Manufacturing (& R&D) - Materials; Textiles; Fibres; Ceramics; Iron & Steel (works).
ET5a	**Membrane Science/ Technology (sub-discipline)** *(Industry/ services)*	Membrane science & technology; Membrane processes; membrane separation/ filtration technology; membrane plants. Services – Membrane consultancy/ services; Membrane plants. Manufacturing (& R&D): Membranes (incl. water treatment membranes); Membrane products; Membrane process chemicals; Membrane (separation/ filtration) systems (inc. those for water treatment).
ET6	**Other Engineering/ Technology** *(Industry/ services)*	General Engineering; Engineering science; Systems science, engineering & technology; Sustainable technology; Innovative technologies; Industrial science, engineering & technology; Production engineering; Human engineering & technology; Marine engineering (Ship research); Nuclear science, engineering & technology; Space science & technology; & other Engineering fields. Services – General engineering services/ consultancy; Industrial services & management; Manufacturing (& R&D) - Engineering systems.
ET7	**Multidisciplinary engineering/ technology**	If cover more than one main engineering/ technology field.

Physical Sciences

PS1	**Chemistry**	Chemistry (General, Applied, Analytical, Interface, Inorganic, Organic, Macromolecular, Physical, Solid State, Technical, Theoretical), Electrochemistry, Industrial chemistry, Radiochemistry, Pulp/paper chemistry, Applied surfactants, Corrosion, Surface treatment, Catalysis, Heavy metals, Polymer Sciences (Reactive polymers, technical polymer chemistry).
PS2	**Physics**	Physics (General, Applied, Chemical)
PS3	**Other Physical Sciences & Multidisciplinary fields**	General physical science, Energy science, Physical & Chemical properties, Molecular/ Macromolecular Science.

Environmental Sciences & Management

ES1	**Atmospheric & Earth**	Atmospheric Sciences, General Earth Sciences, Geological Sciences (Geosciences), Geology, Geochemistry, Nuclear geochemistry, Mineralogy (ore mines, minerals, mineral resources), Crystallography, Land/ Desert research, Limnology, River Basin environment research & management, Tropical sciences

ES2	**Oceanography**	Oceanography, Marine Science, Marine Biology, Marine Pollution
ES3	**Water**	General Water Sciences (inc. hydrology/ hydrosciences), Water resources (& management), Water environment, Water chemistry, Water biology (inc. water/aquatic microbiology/ ecotoxicology, freshwater ecology, hydrobiology), Water management; Water quality (management & control), Water pollution (control), Water purification/ desalination (research), Water development, Water analysis, Groundwater, Drinking water, Wastewater/ sewage (analysis, treatment & management).
ES4	**Other Environmental Sciences & multidisciplinary fields**	General/ Applied Environmental Sciences, Environment research, Environmental management; Environmental (quality) control; Environmental protection, Environmental analysis, Environmental Simulation, Pollution science, Pollution control. Waste management (research); Energy management.

Mathematical, Computer & Information Sciences

MC1	General Mathematics, Mathematical Statistics, Applied Mathematics, Mathematics/ Computer Science, Mathematical methods, General Computer & Information Sciences; Informatics; IT consultancy & services, Modelling (environmental).

Life Sciences

LS1	**Agricultural**	Agriculture, Agricultural Sciences, Agricultural Chemistry, Renewable Resources, Plant Sciences, Soil Science, Conservation, Forestry.
LS2	**Biological**	General Biology, Biological Sciences, Bioscience, Bioresources, Microbiology, Bacteriology, Parasitology, Biochemistry/ Biological chemistry, Bioelectrochemistry, Biomedical sciences, Biorganics, Cellular Biology, Molecular Biology, Molecular Oncology, Ecology, Ecological sciences, Microbial Ecology, Microrganism, Food Sciences, Food microbiology, Food analysis, Food hygiene, Immunology, Virology, Viral diseases, Animal diseases, Medical Zoology, Tropical medicine.
LS3	**Medical**	General Medicine, Pharmacy/ Pharmaceutical sciences, Veterinary Medicine/ Services, General/ Public Health & Hygiene, Health sciences & Other Medical Basic Sciences.
LS4	**Other life sciences & multidisciplinary fields**	General Hygiene, Health & Medical Technologies (laboratory work, clinical analysis), Public Health & Medical Services, Safety (research).

Government & other social related fields

GS1	City/ State government, local authority or council, Research Council, Regional Development Studies, Geography, Research & International affairs, Technology Transfer, Risk management, Solicitor.

MD1 – Multidisciplinary & Other Sciences (not elsewhere classified)

Used when multidisciplinary & interdisciplinary aspects make classification under one main field difficult.

APPENDIX 4A: Interview Template

Opening statement:

- Good morning/afternoon, Introduce us (names, what we do)
- We are interviewing you because you have some experience of industry-academia research collaboration
- As stated in our letter, we will be talking about the role of you and your organisation in stimulating, organising and evaluating university-industry research collaboration schemes such as networks and projects, the perceived benefits of research collaboration, the effectiveness of collaboration in terms of organisation, management and communication, the barriers to effective collaboration and finally best practice elements for successful relationships.
- Before we begin, I would like to draw your attention to some definitions. A 'Network' is a group of people (in this case, academics & industrialists) working together to achieve a shared goal or vision. They are generally informal knowledge exchange groups. A collaborative 'project' is where several partners (academic & industrial) form a consortium in order to carry out a piece of development work on a particular subject which is in their mutual interests. Such projects are generally formal and under a 'contract'.
- This interview should last approximately 45 minutes to 1 hour maximum
- Is it ok if we record the interview with a voice recorder?
- If you wish to pull out at any time, please say something

---

1. *Personal information*

a) *Background*
Could you tell us in brief your educational background and professional experience

b) *Experience*
How many years have you been involved in research management?

c) *Position*
Could you describe your job title, something about what your organisation does, and your own main areas of activity in the organisation.

2. *Experience of university-industry research collaboration*

a) *Origin*
i) What are the primary routes for the initiation of collaborative research schemes? (projects/networks)?
ii) Who initiates the majority of collaborative schemes, academics or industry (or both?)?

3. *Motivations for university-industry research collaboration*

a) *Motivations*
i) What do you think are the main motivations for research collaboration from your point of view?
ii) and the main objectives?
iii) What do you think the main motivations are for industrialists?
iv) and for academics?
v) What do you think the main motivations are for joining collaborative 'networks' over simple collaborative projects?

4. *Nature of university-industry research partnerships*

a) *Value*
What are the benefits of such links to the various parties involved (for industrialists and for academics)?

b) *Duration*
i) What are the typical timescales across which collaborative research projects/networks operate?
ii) Why are they funded across this time period?
iii) Do some projects/networks last longer or end earlier than planned?
iv) Why, if at all, is there a difference?
iv) How do you think collaboration is sustained after the first flush of success (i.e. the first couple of meetings)?
v) Do you have any examples of phenomena which 'kill off' collaboration quickly?

5. *Effectiveness of university-industry research collaboration*

a) *Effectiveness*
i) How would you define 'successful' academic-industry research collaboration?
ii) Do you consider the majority of the research collaborative schemes which you have experience of to be a failure or successful?

b) *Evaluation*
i) Do you evaluate/assess university-industry research partnerships? *If not*, who does?
ii) What tools are used to evaluate their performance?

c) *Good/bad examples*
i) Could you tell us in your own words a brief story of a good example of collaboration?
ii) and a bad example?

6. *Barriers to effective university-industry research collaboration*

a) *Barrier factors*
To what extent are [*factor below*] a barrier to successful collaboration?
i) different organisational cultures
ii) disciplinary backgrounds of individual participants (eductional & professional)
iii) poor communication & information dissemination methods
iv) intellectual property rights
v) lack of face-to-face contact
vi) differences in desired timescales

[Pick up on disciplinary background – How/Why is it a barrier?]

b) *Additional Barriers/problems*
Could you suggest any additional reasons for ineffective industry-academic research collaboration?

7. ***Management of university-industry research collaboration***

a) *Models*
i) Are there any specific management structures or models that are applied to the academic-industry research collaborative schemes which you oversee here?
ii) If *yes*, could you explain how it/they work?

8. ***Communication***

a) *Effectiveness*
What are the strengths and weaknesses of the following communication channels in supporting collaboration?
i) Telephone
ii) Face-to-Face dialogue (one-to-one)
iii) Email
iv) Internet (websites)
v) Workshops/ meetings

b) *Internet*
How can the Internet be exploited to support collaboration?

c) *Timescale*
How long does effective communication take to emerge within a collaborating group?

9. ***Best practice for effective university-industry research collaboration***

a) *Good practice factors*
i) Could you suggest five aspects of effective research collaboration which might be used to formulate best practice?
ii) Please rank these in order of importance.

b) *Other aspects*
Are there any other aspects that have not been covered earlier which you think are relevant for the identification of best practice in industry-university research collaboration?

c) *Guide to best practice*
i) Does your organisation have a guide to best practice in university-industry research partnership schemes?
ii) *If yes*, could we have a copy?

[*Request follow-up contact*]

APPENDIX 4B: Letter for Interview Respondents

Cranfield UNIVERSITY

School of Water Sciences
Cranfield University
Cranfield, Beds.
MK43 0AL
Email: [XXXX]

29 October 2002

Dear [*Name*],

Many thanks for agreeing to be interviewed as part of our research on industry-academia research collaboration. I am writing to both provide you with some background information about the project itself and give you some indication of the interview subject matter.

The effectiveness of university-industry R & D collaboration has become a subject of great interest in recent years, particularly in transdisciplinary research networks where a wide range of scientific, technological and industrial domains are involved. The broad aim of this research is to assess the design and management of academic-industry collaborative research with particular reference to the water sector. To help us identify the main barriers to effective research collaboration and find ways of improving knowledge flow in networks, the project has been classified into three main dimensions: (i) motivations/ perspectives of network members, (ii) communication via networks, and (iii) organisation/ management of networks. A number of primary data resources will be used including: members of live and completed industry-university networks funded by the research councils and the EC; individuals involved in the specification, organisation and evaluation of industry-academic research collaboration schemes, in particular networks and projects in the UK; and website traffic data/ database query usage on network websites. Output from the research will support improvement of industry-academic collaboration in terms of goal setting, management and communication.

You have been asked to be interviewed as you have some professional experience of academic-industry research collaboration. To date, 15 interviews have been arranged with individuals at the UK Research Councils, the Office of Science & Technology (DTI), corporate / industrial liaison departments based at UK universities and independent technology transfer organisations.

The three main objectives of the interviews are:
i) To obtain information on the extent and nature of industry-academia research collaboration
ii) To elicit perceptions on the effectiveness of current/ previous research collaborative projects & networks in terms of organisation, management and communication.
iii) To identify best practice elements for effective industry-academic collaboration.

In particular, I would like to discuss the following main themes during the interview:

- Your own experiences of academic-industry research collaboration
- Perceived benefits of academic-industry research collaboration to the different partners
- Nature of academic-industry collaborative schemes (type, lifecycle, dynamics, etc.)
- Evaluation of academic-industry research collaboration (techniques)
- Effectiveness of research collaborative schemes in terms of organisation, management and communication (models/ modes/ styles)
- Barriers to effective academic-industry research collaboration
- Best practice elements for effective academic-industry research collaboration

The interview should last for approximately 45 minutes to 1 hour maximum. A voice (digital) recorder will be used to record the interview if permitted by you. A small room would, therefore, be best for the interview. Anonymity will be preserved and all the information you give will be treated with confidentiality. We will conform to both university and BPS (British Psychological Society) guidelines. Following transcription of the interview, all recorded tapes will be erased. Unless you indicate otherwise, the information you provide will be anonymised so that no individual association can be made with the data. The data obtained from the interviews will be put together thematically to serve as raw material for analysis of the general findings of the study and the implications for policy / decision making. Comparisons will be made to explore similarities, differences, patterns & thematic connections in interview data. A summary report of the findings will be sent to all interviewees.

If you do not wish to be interviewed or if you have any questions, please do not hesitate to contact us, either by email [*email*] or by telephone *[tel. no.]*.

We look forward to meeting you in November.

Yours sincerely

APPENDIX 4C: Interview Transcript Codes

Theme	*Code*	*Description*
Motivations & Benefits	MOTI-GEN	*General information on motivations for collaboration*
	MOTI-ACAD	*Academic motivations*
	MOTI-IND	*Industrial motivations*
	MOTI-OTHER	*Motivations of other parties e.g. government, charities.*
	MOTI-NETW	*Motivations for networks*
Nature, Effectiveness & Evaluation	NAT-GEN	*Information on nature & effectiveness of collaborative schemes*
	NAT-TIME	*Duration of collaborative project or network*
	SUCCESS-DEF	*Definition for 'successful' collaboration*
	SUCCESS-FACTOR	*Factors that help successful collaboration*
	KILL-FACTOR	*Factors that cause collaboration breakdown*
	EVAL-GEN	*General information on evaluation of collaboration*
	EVAL-METR	*Measures for evaluating collaborations*
	GOOD EG	*Factors in good examples of collaboration*
	BAD EG	*Factors in bad examples of collaboration*
Barriers & Problems	BARR-CULT	*Barriers related to organisational cultures*
	BARR-IPR	*Barriers related to IPR*
	BARR-TIME	*Barriers related to industrial/academic timescales*
	BARR-RES-OBJ	*Barriers related to different research objectives & interests*
	BARR-DISC	*Barriers related to disciplinary backgrounds*
	BARR-COMM	*Barriers related to communication*
	BARR-OTHER	*Other barriers*
Management	MANAG-GEN	*General information on management of collaboration*
	MANAG-AGRE	*Collaboration agreements*
	MANAG-MODEL	*Management structures or models*
Communication	COMM-GEN	*General information on modes of communication in collaboration*
	COMM-F2F	*Face to face communication*
	COMM-EMAIL	*Use of e-mail for communication*
	COMM-INTER	*Use of Internet for communication*
	COMM-PHONE	*Use of phone for communication*
Best Practice	BP-FACTORS	*Best practice factors – issues that would include in best practice guide*

Additional Codes:

Code	*Description*
BACK-PERS/BACK-ORG	*Background information on interviewee & own organisation*
JOB-POS	*Job position – description of interviewee's role in organisation*
EXPE-PERS/EXPE-ORG	*Personal or organisational experience of industry-academia collaboration*
ORG-INFO	*Information on particular organisation or collaborative schemes*
INIT-FACTOR	*Factors that help start or lead to initiation of collaboration*
FACILITATOR	*Phrase (other words: relationship manager, spokesman, honest broker)*
HURDLES	*Phrase (instead of 'barriers')*
CHAMPION	*Phrase (Project or collaboration champion)*
SMEs	*Information on small & medium sized companies*
SECTORAL	*Variations between sectors, fields, etc.*
QUAL of LIFE/SOCIETY	*Impact of collaboration on society & quality of life*
KUDOS	*Phrase (prestige)*
MARRIAGE-BROKER	*Phrase*

APPENDIX 5A: Questionnaire Template

Topics & themes of questions in questionnaire template (shown on next page)

Theme	*Question no.*	*Topics of question*
Characteristics of student	**1**	Name
	43	Age
	44	Previous education
Project characteristics	**2**	Title of project
	3	Year of project
	4	Academic institution
	5	Industrial sponsor(s)
	6	Size of industrial organisation(s)
	9	Time student spends at industrial partner
	37	Extent project characterised by good management, good communication & mutual interest/need.
Motivations & Benefits	**7**	Student's motivations
	8	Benefits to student from industrial & academic sides
	10a	Industrial sponsor's motivations
	10b	Academic partner's motivations
	11a	Benefits to industrial institution
	11b	Benefits to academic institution
	12	Unexpected benefits
Project management	**13**	Project specification
	21	Partner providing most leadership in project
	22	Relationship coordinator/manager
	24	Restrictiveness of project management
	25	Gantt chart/list of deliverables for project
	27	Change of project objectives/methods
	28	Collaboration agreement
	29	Confidentiality agreement
Project 'success'	**14**	Satisfaction with project's progress
	38	Success of collaboration personally, for the industrial side & for the academic side
	39	Extent enjoy research work
	40	Relationship between two parties improved or worsened
Characteristics of industrial & academic supervisors	**15**	Industrial/academic supervisor's understanding of work
	16	Industrial/academic supervisor's enthusiasm about project
	17	Disciplinary backgrounds of industrial & academic supervisors
	18	Compatibility of supervisors' disciplinary backgrounds
	20	Partners' prior collaboration experience
Barriers & Problems	**19**	Differences between partners which cause problems when carrying out project?
	23	Personnel changes in coordination group
	26	Problems with project timescales
	33	Communication problems student & supervisors
	35	Communication problems between industrial & academic supervisors
	36	Comments on other problems encountered in relation to collaboration
Communication	**30**	Frequency of joint project meetings
	31	Communication modes with industrial & academic supervisors
	32	Attendance at industry-academia networking events
	34	Quality of communication over time
Best practice	**42**	Suggestions to help improve collaborative research
Other	**41**	Other comments on process or experience of industry-academia collaboration

The School of
Water Sciences

Cranfield UNIVERSITY

Questionnaire for Engineering Doctorate (Eng D) Students

This questionnaire survey is part of a research project sponsored by EPSRC and conducted by Cranfield University, which aims to improve the design and management of industry-academia collaborative research.

You have been asked to complete this questionnaire because you are involved in an industry-academia collaborative project. We are interested in your personal experiences of this kind of research. Your response is important in helping us understand the effectiveness of collaboration between industry and academia. Your cooperation in completing this questionnaire is greatly appreciated. All responses will be kept strictly confidential.

When responding to questions about your supervision, please consider your primary academic and primary industrial supervisor only. When you have completed the questionnaire, please click on the 'Submit questionnaire' button at the bottom of the page to send it back to us.

If you have any questions or problems regarding the questionnaire or the research project, please contact Juliette Butcher at j.butcher@cranfield.ac.uk

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(please type in the boxes and click on the relevant buttons)

1. **Your name:**

2. **Title of your Engineering Doctorate project:**

3. **Year of project:**

   1st ◯ 2nd ◯ 3rd ◯ 4th ◯

4. **Academic institution:**

5. **Industrial sponsor(s):**

6. **Size of industrial sponsoring organisation(s):** *(please click on one button in each column for each company as appropriate)*
   (headcount = number of employees)

	Industrial sponsor 1	*Industrial sponsor 2*	*Industrial sponsor 3*
Large (headcount > 250)	◯	◯	◯
Medium (51-250)	◯	◯	◯
Small (< 51)	◯	◯	◯

7. **Please describe briefly your motivations for doing an Engineering Doctorate rather than a standard Ph D:**

8. **Please list three benefits that you have personally gained from each side (industrial / academic) whilst carrying out the project:** *(e.g. skills, etc.)*

   a. ***From the industrial side:***
      i.
      ii.
      iii.

   b. ***From the academic side:***
      i.
      ii.
      iii.

9. **Roughly how much of your time do you spend working at the industrial collaborator site?**

   - Less than 25%
   - 25%
   - 50%
   - 75%
   - More than 75%

10. **We are interested in the motivations for collaboration of the various partners in an Eng D project. Please complete each of the following statements using the scale shown to indicate how true they are in the case of your project:**

    a. ***My industrial sponsor's motivation to participate in my project is...***
    (please click on one button for each statement)

	not at all true				*very true*	*uncertain*
i. ...to extend their knowledge base	1	2	3	4	5	uc
ii. ...to have access to university facilities / resources	1	2	3	4	5	uc
iii. ...to have access to students	1	2	3	4	5	uc
iv. ...to boost their sales / income	1	2	3	4	5	uc
v. ...to avoid in-house investment in long-term / riskier projects	1	2	3	4	5	uc
vi. ...to have immediate problem solving	1	2	3	4	5	uc
vii. ...to raise their profile within society	1	2	3	4	5	uc
viii. ...to obtain prestige in marketplace	1	2	3	4	5	uc

    b. ***My academic institution's motivation to participate in my project is ...***

(please click on one button for each statement)

	not at all true				*very true*	*uncertain*
i. ...to generate income	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
ii. ...to find & work on real / industry's leading edge problems	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
iii. ...to develop individual reputations	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
iv. ...to see research being applied	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
v. ...to have an impact on society	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
vi. ...to expose students to real world problems	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
vii. ...to improve employment opportunities for students	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
viii. ...to have access to industry facilities	1 ○	2 ○	3 ○	4 ○	5 ○	uc ○

11. **Please list three benefits that you think <u>each</u> partner institution (industrial / academic) gain from the Engineering Doctorate project:**

a. ***Benefits to <u>industrial</u> institution:***

i.

ii.

iii.

b. ***Benefits to <u>academic</u> institution:***

i.

ii.

iii.

12. **Have there been any unexpected benefits from the project?**

Yes ○ No ○ Don't know ○

a. **If <u>Yes</u>, please describe briefly what the benefits were:**

13. **How well do you consider the project to have been specified?**

1 ○	2 ○	3 ○	4 ○	5 ○	uc ○
poorly specified				*very well specified*	*uncertain*

14. **How satisfied are you with your project's progress?**

1 ○ 2 ○ 3 ○ 4 ○ 5 ○ uc ○

not at all satisfied | *very satisfied* | *uncertain*

15. **To what extent do you feel that your supervisors on <u>each</u> side understand your work?**

a. ***<u>Industrial</u> supervisor:***

1 ◌ 2 ◌ 3 ◌ 4 ◌ 5 ◌ uc ◌

not at all | *very well* | *uncertain*

b. ***<u>Academic</u> supervisor:***

1 ◌ 2 ◌ 3 ◌ 4 ◌ 5 ◌ uc ◌

not at all | *very well* | *uncertain*

16. **How enthusiastic are your supervisors about the project?**

a. ***<u>Industrial</u> supervisor:***

1 ◌ 2 ◌ 3 ◌ 4 ◌ 5 ◌ uc ◌

not at all enthused | *very enthused* | *uncertain*

b. ***<u>Academic</u> supervisor:***

1 ◌ 2 ◌ 3 ◌ 4 ◌ 5 ◌ uc ◌

not at all enthused | *very enthused* | *uncertain*

17. **Please describe briefly the disciplinary (educational / professional) backgrounds of your supervisors:** *(i.e. their job position, the subject fields they specialise in, etc.)*

a. ***<u>Industrial</u> supervisor:***

b. ***<u>Academic</u> supervisor:***

18. **How compatible are the disciplinary backgrounds of your industrial and academic supervisors?**

1 ◌ 2 ◌ 3 ◌ 4 ◌ 5 ◌ uc ◌

not at all compatible | *very compatible* | *uncertain*

a. **If you consider them to be <u>poorly</u> compatible, is this a problem?**

Yes ◌ No ◌ Don't know ◌ Not applicable ◌

19. **Are there any differences between the industrial and academic partners which cause problems when carrying out or reporting on the project?**

Yes ◌ No ◌ Don't know ◌

a. **If Yes, please describe briefly:**

20. **Had the industrial and academic partners worked together prior to your particular project?**

Yes ◠ No ◠ Don't know ◠

21. **Which partner provides most leadership in the project?**

Industrial ◠ Academic ◠ Equal ◠

22. **Who coordinates / manages the relationship (e.g. chairs meetings)?**

Industry ◠ Academic ◠ Both ◠

23. **Have there been any personnel changes in the coordination group?** *(e.g. change of supervisor?)*

Yes ◠ No ◠ Not applicable ◠

a. **If Yes, at what stage (year) of your project did this happen?**

1st ◠ 2nd ◠ 3rd ◠ 4th ◠

b. **Were the personnel involved in the change industrial or academic, or both?**

Industrial ◠ Academic ◠ Both ◠

c. **Did this have any effect on the project?**

Yes ◠ No ◠ Not sure ◠

24. **How restrictive is the project management / supervision?** *(i.e. how inflexible is the project's structure in terms of objectives, procedures, timescales, etc.)*

1 ◠	2 ◠	3 ◠	4 ◠	5 ◠	uc ◠
not at all restrictive				*very restrictive*	*uncertain*

25. **Has a GANTT chart or a list of deliverables / milestones for the project been agreed?**

Yes ◠ No ◠ Not sure ◠

26. **Have you encountered any problems with regard to project timescales?**

Yes ◠ No ◠ Not applicable ◠

27. **Have the project objectives or research methods changed during the lifetime of the project?**

Yes ◠ No ◠ Not applicable ◠

28. **Is there a collaboration agreement in force?**

Yes ◠ No ◠ Not sure ◠

a. **If Yes, who authored the collaboration agreement?**

Industrial partner ◠ Academic partner ◠ Both ◠ Don't know ◠

b. **Have you been asked to sign the collaboration agreement?**

Yes ○ No ○ Not sure ○

c. **Have any problems been encountered in relation to the collaboration agreement?**

Yes ○ No ○ Not sure ○

29. **Have you been asked to sign a confidentality agreement?**

Yes ○ No ○ Not sure ○

30. **How frequently are joint (industry / academic) project meetings held?**

- ○ Less than once a year
- ○ Once a year
- ○ Quarterly
- ○ Once a month
- ○ More frequently than once a month

31. **How important are each of these communication modes between...**

a. ***... you and your <u>industrial</u> supervisor:*** *(please click on one button for each statement)*

	Low score				*High score*
i. E-mail	1 ○	2 ○	3 ○	4 ○	5 ○
ii. Telephone	1 ○	2 ○	3 ○	4 ○	5 ○
iii. Face-to-Face	1 ○	2 ○	3 ○	4 ○	5 ○

b. ***... you and your <u>academic</u> supervisor:*** *(please click on one button for each statement)*

	Low score				*High score*
i. E-mail	1 ○	2 ○	3 ○	4 ○	5 ○
ii. Telephone	1 ○	2 ○	3 ○	4 ○	5 ○
iii. Face-to-Face	1 ○	2 ○	3 ○	4 ○	5 ○

32. **Have you attended any industry-academia networking events?**

Yes ○ No ○ Not sure ○

33. **Have you encountered any communication problems with your supervisors?** *(e.g. jargon, lack of contact, etc.)*

Yes ○ No ○ Not sure ○

a. **If <u>Yes</u>, with who?**

Industrial ○ Academic ○ Both ○

34. **Has the quality of communication between you and your supervisors improved or worsened over time?**

Improved ○ Worsened ○ Not sure ○

35. **Have there been any communication problems between the industrial and academic partners?**

Yes ◠ No ◠ Not sure ◠

36. **Please comment on any other problems which you have encountered in relation to industry-academia collaboration that have not been covered earlier:**

37. **To what extent is the project characterised by:** *(please click on one button for each statement)*

	Low score				*High score*
a. **Good management?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠
b. **Good communication?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠
c. **Mutual interest or need?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠

38. **How would you measure the success of the collaboration to date?** *(please click on one button for each statement)*

	Low score				*High score*
a. **Personally?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠
b. **For the Industrial side?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠
c. **For the Academic side?**	1 ◠	2 ◠	3 ◠	4 ◠	5 ◠

39. **To what extent are you enjoying your research work?**

1 ◠	2 ◠	3 ◠	4 ◠	5 ◠	uc ◠
not at all				*very much*	*uncertain*

40. **Since you started the engineering doctorate do you feel that the relationship between the two parties (industry / academic) has improved or worsened?**

Improved ◠ Worsened ◠ Not sure ◠

41. **Have you any other comments on the process or experience of industry-academia collaboration?**

42. **Have you any suggestions to help improve collaborative research?**

43. **Please enter your age:** *(years)*

44. **Previous Education:** *(e.g. HND, BSc, MSc, etc.)*

Qualification *Field of study* *Year completed*

This is the end of the questionnaire. Please click the submit questionnaire button when ready. Your answers will be sent automatically to Cranfield University.

Submit questionnaire

Please enter your e-mail address in the box below if you would like us to acknowledge receipt of your completed questionnaire:

Thank you very much for your cooperation.

Clear form

Juliette Butcher
School of Water Sciences, Cranfield University
j.butcher@cranfield.ac.uk

15 October, 2003

APPENDIX 5B: Questionnaire Distribution E-mails

Subject: Industry-Academia Research Collaboration Survey

Dear *[EngD centre contact name]*,

Earlier this year we asked if you would help us disseminate a survey on industry-academia collaboration to your Engineering Doctorate students. Please find below a message which we would like you to distribute to your EngD students which contains a link to our online questionnaire. You just need to delete the top section of this email and forward the message below the dotted line to your students.

Please do not hesitate to contact me if you have any problems or questions regarding this questionnaire.

Many thanks for your cooperation.

....

Dear Student,

As part of our research project which aims to improve the design and management of industry-academia collaborative research, we are conducting a questionnaire survey in order to obtain information on students' experiences of this kind of research.

As you are involved in an industry-academia collaborative project, we would be grateful if you could complete our web based questionnaire. It should take no longer than 15 minutes to complete. Please click on the link below to be taken to the online questionnaire and once completed just click (once) on the submit buttons which will automatically send your answers back to us.

The link is: http://www.rmcs.cranfield.ac.uk/waterscience/questionnaire.html

If you would like us to acknowledge receipt of your completed questionnaire, please enter your email address in the text box at the bottom of the questionnaire.

Please do not hesitate to contact me by email [*email*] if you have any comments or questions.

Thank you in advance for your help.

Dear CASE supervisor,

I am an EPSRC funded PhD student from Cranfield University who is investigating models of collaboration between academia and industry. As part of this study we would like to carry out a survey of students working in collaborative environments, including those funded under the CASE scheme.

We would, therefore, be grateful if you could cooperate in our survey by distributing the message below to your CASE student(s) which contains a link to our online questionnaire which we would like them to complete. You just need to delete the top section of this email and forward the message below the dotted line to your students.

[Research Council] are aware of this survey and have actively participated in previous phases of the study. Please do not hesitate to contact me by email or my supervisor Dr Paul Jeffrey, if you have any questions regarding this questionnaire or the project. Thank you for your time and attention.

Yours sincerely

....

Dear Student,

As part of our research project which aims to improve the design and management of industry-academia collaborative research, we are conducting a questionnaire survey in order to obtain information on students' experiences of this kind of research.

As you are involved in an industry-academia collaborative project, we would be grateful if you could complete our web based questionnaire. It should take no longer than 15 minutes to complete. Please click on the link below to be taken to the online questionnaire and once completed just click (once) on the submit buttons which will automatically send your answers back to us.

The link is: http://www.rmcs.cranfield.ac.uk/waterscience/casequest.html

If you would like us to acknowledge receipt of your completed questionnaire, please enter your email address in the text box at the bottom of the questionnaire.

Please do not hesitate to contact me by email *[email]* if you have any comments or questions.

Thank you in advance for your help.

APPENDIX 5C: Student Questionnaire Data Coding Sheets

Codes for Database 1 (closed-type question responses)

Column no.	Question no.	Variable name	Variable Label & Codes [for all variables: 99 = missing or 'not applicable']	Measure
1	1	stu_id	Student ID	
2		type_prj	Type of studentship **1 = CASE** **2 = EngD**	Nominal
3	3	year_prj	Year of project **1 = 1st** **2 = 2nd** **3 = 3rd** **4 = 4th** **5 = part-time**	Nominal
4	6	siz_ind1	Size main industrial sponsor **1 = small** **2 = medium** **3 = large**	Nominal
5	9	time_ind	Time spend working at industry **1 = less than 25%** **2 = 25%** **3 = 50%** **4 = 75%** **5 = more than 75%**	Ordinal
6	10ai	mot_ind1	Motivation industry – extend knowledge base **1 = 1 (not true at all)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very true)** **98 = uc (uncertain)**	Ordinal
7	10aii	mot_ind2	Motivation industry – access university facilities **(codes as mot-ind1 above)**	Ordinal
8	10aiii	mot_ind3	Motivation industry – access students **(codes as mot-ind1 above)**	Ordinal
9	10aiv	mot_ind4	Motivation industry – boost sales/income **(codes as mot-ind1 above)**	Ordinal
10	10av	mot_ind5	Motivation industry– avoid in-house investment **(codes as mot-ind1 above)**	Ordinal
11	10avi	mot_ind6	Motivation industry – immediate prob. solving **(codes as above)**	Ordinal
12	10avii	mot_ind7	Motivation industry – raise profile within society **(codes as mot-ind1 above)**	Ordinal
13	10aviii	mot_ind8	Motivation industry – obtain prestige in market **(codes as mot-ind1 above)**	Ordinal
14	10bi	mot_aca1	Motivation academic – generate income **(codes as mot-ind1 above)**	Ordinal
15	10bii	mot_aca2	Motivation academic – find/work on real problems **(codes as mot-ind1 above)**	Ordinal
16	10biii	mot_aca3	Motivation academic – develop individual reputations **(codes as mot-ind1 above)**	Ordinal
17	10biv	mot_aca4	Motivation academic – see research being applied **(codes as mot-ind1 above)**	Ordinal
18	10bv	mot_aca5	Motivation academic – have impact on society **(codes as mot-ind1 above)**	Ordinal
19	10bvi	mot_aca6	Motivation academic – expose students to real problems **(codes as mot-ind1 above)**	Ordinal
20	10bvii	mot_aca7	Motivation academic – student employment opportunities **(codes as mot-ind1 above)**	Ordinal
21	10bviii	mot_aca8	Motivation academic – access industry facilities **(codes as mot-ind1 above)**	Ordinal

Column no.	Question no.	Variable name	Variable Label & Codes	Measure
22	12	unex_ben	Unexpected benefits? **1 = yes** **2 = no** **3 = don't know**	Nominal
23	13	spec_prj	How well specified is the project? **1 = 1 (poorly specified)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very well specified)** **98 = uc (uncertain)**	Ordinal
24	14	sati_prj	How satisfied with project progress? **1 = 1 (not at all satisfied)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very satisfied)** **98 = uc (uncertain)**	Ordinal
25	15a	und_ind	Extent industrial supervisor understands work **1 = 1 (not at all)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very well)** **98 = uc (uncertain)**	Ordinal
26	15b	und_aca	Extent academic supervisor understands work **(codes as und_ind above)**	Ordinal
27	16a	enth_ind	How enthusiastic industrial supervisor about project **1 = 1 (not at all enthused)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very enthused)** **98 = uc (uncertain)**	Ordinal
28	16b	enth_aca	How enthusiastic academic supervisor about project **(codes as enth_ind above)**	Ordinal
29	18	comp_sup	Compatibility of supervisor's disciplinary backgrounds **1 = 1 (not at all compatible)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very compatible)** **98 = uc (uncertain)**	Ordinal
30	18a	comp_prb	If qu 18 = poorly compatible – problem? **1 = yes** **2 = no** **3 = don't know** **99 = not applicable**	Nominal
31	19	diff_prb	Differences between partners cause problems? **1 = yes** **2 = no** **3 = don't know**	Nominal
32	20	work_bef	Partners worked before project? **1 = yes** **2 = no** **3 = don't know**	Nominal
33	21	lead_prj	Which partner provides most leadership? **1 = Industrial** **2 = Academic** **3 = Equal**	Nominal
34	22	coor_prj	Who coordinates/manages relationship? **1 = Industrial** **2 = Academic** **3 = Both**	Nominal

Column no.	Question no.	Variable name	Variable Label & Codes	Measure
35	23	pers_chg	Personnel changes in coordination group? **1 = yes** **2 = no** **99 = not applicable**	Nominal
36	23a	year_chg	If qu 23 = yes, at what stage of project happened? **1 = 1st** **2 = 2nd** **3 = 3rd** **4 = 4th** **5 = Other**	Nominal
37	23b	pers_inv	Personnel involved in change **1 = Industrial** **2 = Academic** **3 = Both**	Nominal
38	23c	eff_proj	Personnel change affect project? **1 = yes** **2 = no** **3 = not sure**	Nominal
39	24	prj-mgm	How restrictive is project management? **1 = 1 (not at all restrictive)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very restrictive)** **98 = uc (uncertain)**	Ordinal
40	25	gantt_ch	Gantt chart or list deliverables/milestones for project? **1 = yes** **2 = no** **3 = not sure**	Nominal
41	26	prj_time	Encountered problems with project timescales? **1 = yes** **2 = no** **99 = not applicable**	Nominal
42	27	chg_obj	Changed projective objectives/research methods? **1 = yes** **2 = no** **99 = not applicable**	Nominal
43	28	coll_agr	Collaboration agreement in force? **1 = yes** **2 = no** **3 = not sure**	Nominal
44	28a	auth_agr	If qu 28 = yes, who authored agreement? **1 = Industrial partner** **2 = Academic partner** **3 = Both** **4 = don't know**	Nominal
45	28b	sign_agr	Asked to sign agreement? **1 = yes** **2 = no** **3 = not sure**	Nominal
46	28c	prob_agr	Encountered any problems with agreement? **1 = yes** **2 = no** **3 = not sure**	Nominal
47	29	conf_agr	Asked to sign confidentiality agreement? **1 = yes** **2 = no** **3 = not sure**	
48	30	freq_mtg	How frequently joint project meetings held? **1 = Less than once a year** **2 = Once a year** **3 = Quarterly** **4 = Once a month** **5 = more frequently than once a month**	Ordinal

Column no.	Question no.	Variable name	Variable Label & Codes	Measure
49	31ai	ind_emal	Importance of email for comm. ind. supervisor **1 = 1 (low score)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (high score)**	Scale
50	31aii	ind_tele	Importance of phone for comm. with ind. supervisor **(codes as ind_emal above)**	Scale
51	31aiii	ind_f2f	Importance of F2F for comm. with ind. supervisor **(codes as ind_emal above)**	Scale
52	31bi	aca_emal	Importance of email for comm. with acad. supervisor **(codes as ind_emal above)**	Scale
53	31bii	aca_tele	Importance of phone for comm. with acad. supervisor **(codes as ind_emal above)**	Scale
54	31biii	aca_f2f	Importance of F2F for comm. with acad. supervisor **(codes as ind_emal above)**	Ordinal
55	32	netw_eve	Attended any ind-acad networking events? **1 = yes** **2 = no** **3 = not sure**	Nominal
56	33	comm_prb	Encountered any comm. problems with supervisors? **1 = yes** **2 = no** **3 = not sure**	Nominal
57	33a	comm_who	If qu 33 = yes, with who? **1 = Industrial** **2 = Academic** **3 = Both**	Nominal
58	34	comm_qul	Quality of communication over time **1 = improved** **2 = worsened** **3 = not sure**	Nominal
59	35	comm_ptr	Any communication problems between partners? **1 = yes** **2 = no** **3 = not sure**	Nominal
60	37a	gd_mgmt	Extent project characterised by good management? **1 = 1 (low score)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (high score)**	Scale
61	37b	gd_comm	Extent project characterised by good communication? **(codes as gd_mgmt above)**	Scale
62	37c	mut_inte	Extent project characterised by mutual interest/need? **(codes as gd_mgmt above))**	Scale
63	38a	succ_per	Success of collaboration personally **1 = 1 (low score)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (high score)**	Scale
64	38b	succ_ind	Success of collaboration for industrial side **(codes as succ_per above)**	Scale
65	38c	succ_aca	Success of collaboration for academic side **(codes as succ_per above)**	Scale
66		succ_sum	Overall success (sum of succ-per, succ_ind & succ_aca)	Scale
67	39	ext_enjy	Extent enjoy research work **1 = 1 (not at all)** **2 = 2** **3 = 3** **4 = 4** **5 = 5 (very much)** **98 = uc (uncertain)**	Ordinal

Column no.	Question no.	Variable name	Variable Label & Codes	Measure
68	40	rel_prts	Relationship between two parties improved or worsened? **1 = improved** **2 = worsened** **3 = not sure**	Nominal
69	43	stud_age	Student's age ***(years)***	Scale
70		age_grp	Age group **1 = 21-25** **2 = 26-30** **3 = 31-35** **4 = 36-40** **5 = 41-45** **6 = 46-50** **7 = 51-55**	Ordinal
71		res_coun	Research Council **1 = EPSRC** **2 = ESRC** **3 = NERC** **4 = PPARC** **5 = BBSRC**	Nominal

CATEGORIES for Database 2 (responses to questions 7, 8 & 11)

Column no.	Question no.	Variable name	Variable Label & Codes
1	1	stu_id	Student ID
2	7	mot_stu1	Student's motivations for project (see categories below)
3	7	mot_stu2	
4	7	mot_stu3	
5	7	mot_stu4	
6	11ai	ben_ind1	Benefits to industrial institution (see categories below)
7	11aii	ben_ind2	
8	11aiii	ben_ind3	
9	11bi	ben_aca1	Benefits to academic institution (see categories below)
10	11bii	ben_aca2	
11	11biii	ben_aca3	
12	8ai	pbenind1	Personal benefits from industrial side (see categories below)
13	8aii	pbenind2	
14	8aiii	pbenind3	
15	8bi	pbenaca1	Personal benefits from academic side (see categories below)
16	8bii	pbenaca2	
17	8biii	pbenaca3	

Student's motivations for project (mot_stu)

Value	Category label	Description
1	**ACRESFAC**	Access to resources/facilities/data
2	**CONTCOLL**	Contacts/Collaboration (with other researchers)
3	**CAREER**	Employment opportunities
4	**INDEXPE**	Industrial experience (exposure to work environment, style, etc.)
5	**INDINPUT**	Input of industrial expert
6	**INTRPROJ**	Interesting project
7	**KNWEXBTH**	Knowledge & experience of both (institutions)
8	**MONEY**	Money (for themselves or for project)
9	**NOMOTIV**	No motivation for specifically doing a CASE project
10	**PREVEMPL**	Previously employed (maintain link with organisation)
11	**RESAPPLC**	Research application (relevant, 'real', benefit society)
12	**SKLLTRNG**	Training/Skills (incl. MBA for EngD)
98	**98**	Do not understand response/cannot categorise
99	**99**	no response

Benefits to Industrial Institution (ben_ind)

Value	Category label	Description
1	**ACCESTUD**	Access to student (research assistance, extra manpower, use of their skills/knowledge/time)
2	**ACEXKNOW**	Access/exchange academic knowledge/expertise/ideas (& enhance knowledge)
3	**ACRESFAC**	Access to facilities/resources/data (university)
4	**LINKCONT**	Links/contacts with academia (& build up/develop/improve)
5	**CHEAPRES**	Cheap research/labour
6	**CURRAWAR**	Current awareness (keep up to date with latest research/approaches)
7	**DIFFPERS**	Different perspective (new/outside perspective)
9	**EXTENRES**	Extend/expand research (new areas/expand research dept)
10	**FUTROPPO**	Further/Future research/collaboration opportunities
11	**INDFUTUR**	Ensure future of industry (low risk research, long term investment, income)
12	**ACAINPUT**	Academic input (advice/skills/support/feedback, etc.)
13	**POTLEMPL**	Potential employees (well trained)
14	**PRESTIGE**	Prestige/Profile (general/academic/public/market also from publications/conferences)
15	**PROUTPUT**	Project outputs (research findings/results/res.applic.)
16	**PUBLICAT**	Publications (more)
17	**QUALRES**	Quality research (longterm, indepth, independent, basic/pure research)
18	**RESINTR**	Research in area of interest/importance (specific to needs)
19	**PROBSOLV**	Problem solving (immediate/answer questions)
98	**98**	Do not understand response/cannot categorise
99	**99**	no response/none

Benefits to Academic Institution (ben_aca)

1	**ACRESFAC**	Access to facilities/resources/data (industry)
2	**ACEXKNOW**	Access/exchange indus. knowledge/expertise/ideas (& enhance knowledge)
3	**LINKCONT**	Links/contacts with industry (& build up/develop/improve)
4	**CHEAPRES**	Cheap work
5	**COLLAEXP**	Collaborative expertise (experience)
7	**EXTENRES**	Extend/expand research scope/group
8	**FUTROPPO**	Future/Further opportunities (work/money etc.)
9	**INDINPUT**	Industrial input (support/supervision)
10	**MONEY**	Money
11	**PRESTIGE**	Prestige
12	**RESAPPLC**	Research application ('real' world research/relevant/industrial probs/wider benefits)
13	**INTRPROJ**	Interesting project (research in area of interest)
14	**STUDEMPL**	Student employment (opportunities)
15	**ATTRSTUD**	Help attract students (to uni/dept)
16	**STUDTRNG**	Student training (& expose to real world)
17	**INDPERSP**	Industrial perspective (understand)
18	**UPTODATE**	Up to date research
19	**PUBLICAT**	Publications
20	**PROUTPUT**	Project results
98	**98**	Do not understand response/cannot categorise
99	**99**	no response/none

Benefits to Student from Industrial side (pbenind)

1	**CONTNETW**	Contacts/networking
2	**ACRESFAC**	Access to facilities/resources/data/information
3	**SKLLTRNG**	Skills/training (communication/presentation/practical/fieldwork/laboratory)
4	**ACKNWEXP**	Access ind. expertise/knowledge (& enhance knowledge (of subject))
5	**CAREER**	Employment opportunities or insight/guide future employment
6	**INDEXPE**	Industrial experience (enhance knowledge of industry, industrial research/work experience)
8	**INDPERSP**	Industrial perspective
9	**INDINPUT**	Industrial input (support/supervision/help)
10	**MONEY**	Money
11	**PRJMGMT**	Project management (skills/time management/direction/planning/design)
12	**RESAPPLC**	Research application (real world/relevant & relevant work experience)
13	**PRESIND**	Presentation of work to industry
14	**TRAVCONF**	Travel/conference
15	**CONFID**	Confidence
16	**BROADSC**	Broader scope (wider research focus/new area)
98	**98**	Do not understand response/cannot categorise
99	**99**	no response/none

Benefits to Student from Academic side (pbenaca)

1	**ACAINPUT**	Academic advice/guidance/supervision/support (& from other students)
2	**CONTNETW**	Academic Contacts/collaboration/networking (& team working) (incl. social)
3	**ACADEXPE**	Academic experience (enhance knowledge of academia, academic research/work env.)
4	**ACKNWEXP**	Access to academic knowledge/expertise (& enhance knowledge (of subject))
5	**ACRESFAC**	Access to facilities/resources/data (& office space)
7	**INDEPTH**	In-depth focus/knowledge (or focused/quality research)
8	**CONFID**	Confidence
9	**CONFPRES**	Conferences/presentation (not skills)
10	**ACADTHKG**	Academic thinking (critical approach/intellectual/ theoretical)
11	**FLEXIBIL**	Flexibility (freedom in research/direction. independent, relaxed environment, etc.)
12	**SKLLTRNG**	Skills/training (e.g. laboratory/ research/ writing/ presentation)
13	**PRJMGMT**	Project management (skills/time management/organisation)
14	**MONEY**	Money
15	**RESAPPLC**	Research application
16	**MOTIV**	Motivation (self)
98	**98**	Do not understand response/cannot categorise
99	**99**	no response/none

APPENDIX 5D: Questionnaire Database 1 - Frequency Tables

EngD or CASE?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	CASE	284	81.6	81.6	81.6
	EngD	64	18.4	18.4	100.0
	Total	348	100.0	100.0	

Year of Project

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1st	71	20.4	20.8	20.8
	2nd	112	32.2	32.7	53.5
	3rd	133	38.2	38.9	92.4
	4th	23	6.6	6.7	99.1
	part-time	3	.9	.9	100.0
	Total	342	98.3	100.0	
Missing	99	6	1.7		
Total		348	100.0		

Size industrial sponsor (main)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	small	40	11.5	11.6	11.6
	medium	49	14.1	14.2	25.8
	large	256	73.6	74.2	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Time spend working at industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 25%	261	75.0	75.7	75.7
	25%	31	8.9	9.0	84.6
	50%	14	4.0	4.1	88.7
	75%	1	.3	.3	89.0
	more than 75%	38	10.9	11.0	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Motivation industry - extend knowledge base

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	12	3.4	3.7	3.7
	2	15	4.3	4.6	8.3
	3	40	11.5	12.2	20.5
	4	111	31.9	33.9	54.4
	very true	149	42.8	45.6	100.0
	Total	327	94.0	100.0	
Missing	uncertain	16	4.6		
	99	5	1.4		
	Total	21	6.0		
Total		348	100.0		

Motivation industry - access university facilities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	81	23.3	26.2	26.2
	2	84	24.1	27.2	53.4
	3	50	14.4	16.2	69.6
	4	51	14.7	16.5	86.1
	very true	43	12.4	13.9	100.0
	Total	309	88.8	100.0	
Missing	uncertain	34	9.8		
	99	5	1.4		
	Total	39	11.2		
Total		348	100.0		

Motivation industry - access students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	47	13.5	16.4	16.4
	2	66	19.0	23.0	39.4
	3	71	20.4	24.7	64.1
	4	65	18.7	22.6	86.8
	very true	38	10.9	13.2	100.0
	Total	287	82.5	100.0	
Missing	uncertain	56	16.1		
	99	5	1.4		
	Total	61	17.5		
Total		348	100.0		

Motivation industry - boost sales/income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	115	33.0	41.1	41.1
	2	54	15.5	19.3	60.4
	3	41	11.8	14.6	75.0
	4	44	12.6	15.7	90.7
	very true	26	7.5	9.3	100.0
	Total	280	80.5	100.0	
Missing	uncertain	63	18.1		
	99	5	1.4		
	Total	68	19.5		
Total		348	100.0		

Motivation industry - avoid in-house investment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	77	22.1	29.1	29.1
	2	55	15.8	20.8	49.8
	3	44	12.6	16.6	66.4
	4	65	18.7	24.5	90.9
	very true	24	6.9	9.1	100.0
	Total	265	76.1	100.0	
Missing	uncertain	77	22.1		
	99	6	1.7		
	Total	83	23.9		
Total		348	100.0		

Motivation industry - immediate problem solving

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	73	21.0	24.3	24.3
	2	76	21.8	25.2	49.5
	3	79	22.7	26.2	75.7
	4	53	15.2	17.6	93.4
	very true	20	5.7	6.6	100.0
	Total	301	86.5	100.0	
Missing	uncertain	42	12.1		
	99	5	1.4		
	Total	47	13.5		
Total		348	100.0		

Motivation industry - raise profile within society

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	54	15.5	18.8	18.8
	2	55	15.8	19.1	37.8
	3	64	18.4	22.2	60.1
	4	72	20.7	25.0	85.1
	very true	43	12.4	14.9	100.0
	Total	288	82.8	100.0	
Missing	uncertain	55	15.8		
	99	5	1.4		
	Total	60	17.2		
Total		348	100.0		

Motivation industry - obtain prestige in market

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	60	17.2	22.3	22.3
	2	65	18.7	24.2	46.5
	3	64	18.4	23.8	70.3
	4	51	14.7	19.0	89.2
	very true	29	8.3	10.8	100.0
	Total	269	77.3	100.0	
Missing	uncertain	74	21.3		
	99	5	1.4		
	Total	79	22.7		
Total		348	100.0		

Motivation academic - generate income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	21	6.0	6.7	6.7
	2	30	8.6	9.5	16.2
	3	55	15.8	17.5	33.7
	4	93	26.7	29.5	63.2
	very true	116	33.3	36.8	100.0
	Total	315	90.5	100.0	
Missing	uncertain	28	8.0		
	99	5	1.4		
	Total	33	9.5		
Total		348	100.0		

Motivation academic - find/work on real problems

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	12	3.4	3.7	3.7
	2	32	9.2	10.0	13.7
	3	52	14.9	16.2	29.9
	4	109	31.3	34.0	63.9
	very true	116	33.3	36.1	100.0
	Total	321	92.2	100.0	
Missing	uncertain	21	6.0		
	99	6	1.7		
	Total	27	7.8		
Total		348	100.0		

Motivation academic - develop individual reputations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	14	4.0	4.7	4.7
	2	54	15.5	17.9	22.6
	3	73	21.0	24.3	46.8
	4	104	29.9	34.6	81.4
	very true	56	16.1	18.6	100.0
	Total	301	86.5	100.0	
Missing	uncertain	41	11.8		
	99	6	1.7		
	Total	47	13.5		
Total		348	100.0		

Motivation academic - see research being applied

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	11	3.2	3.4	3.4
	2	19	5.5	5.9	9.3
	3	57	16.4	17.7	27.0
	4	140	40.2	43.5	70.5
	very true	95	27.3	29.5	100.0
	Total	322	92.5	100.0	
Missing	uncertain	20	5.7		
	99	6	1.7		
	Total	26	7.5		
Total		348	100.0		

Motivation academic - have impact on society

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	19	5.5	6.4	6.4
	2	42	12.1	14.2	20.7
	3	85	24.4	28.8	49.5
	4	95	27.3	32.2	81.7
	very true	54	15.5	18.3	100.0
	Total	295	84.8	100.0	
Missing	uncertain	47	13.5		
	99	6	1.7		
	Total	53	15.2		
Total		348	100.0		

Motivation academic - expose students to real problems

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	6	1.7	1.9	1.9
	2	35	10.1	11.0	12.9
	3	73	21.0	23.0	36.0
	4	122	35.1	38.5	74.4
	very true	81	23.3	25.6	100.0
	Total	317	91.1	100.0	
Missing	uncertain	25	7.2		
	99	6	1.7		
	Total	31	8.9		
Total		348	100.0		

Motivation academic - student employment opportunities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	8	2.3	2.5	2.5
	2	36	10.3	11.3	13.8
	3	60	17.2	18.8	32.5
	4	131	37.6	40.9	73.4
	very true	85	24.4	26.6	100.0
	Total	320	92.0	100.0	
Missing	uncertain	21	6.0		
	99	7	2.0		
	Total	28	8.0		
Total		348	100.0		

Motivation academic - access industry facilities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not true at all	38	10.9	12.0	12.0
	2	46	13.2	14.5	26.5
	3	55	15.8	17.4	43.8
	4	100	28.7	31.5	75.4
	very true	78	22.4	24.6	100.0
	Total	317	91.1	100.0	
Missing	uncertain	24	6.9		
	99	7	2.0		
	Total	31	8.9		
Total		348	100.0		

Unexpected benefits?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	66	19.0	19.1	19.1
	no	156	44.8	45.2	64.3
	don't know	123	35.3	35.7	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

How well specified is the project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	poorly specified	22	6.3	6.5	6.5
	2	38	10.9	11.2	17.7
	3	84	24.1	24.8	42.5
	4	120	34.5	35.4	77.9
	very well specified	75	21.6	22.1	100.0
	Total	339	97.4	100.0	
Missing	uncertain	4	1.1		
	99	5	1.4		
	Total	9	2.6		
Total		348	100.0		

How satisfied with project's progress?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all satisfied	6	1.7	1.8	1.8
	2	42	12.1	12.4	14.1
	3	102	29.3	30.0	44.1
	4	134	38.5	39.4	83.5
	very satisfied	56	16.1	16.5	100.0
	Total	340	97.7	100.0	
Missing	uncertain	5	1.4		
	99	3	.9		
	Total	8	2.3		
Total		348	100.0		

Extent industrial supervisor understands work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all	13	3.7	4.0	4.0
	2	40	11.5	12.2	16.1
	3	64	18.4	19.5	35.6
	4	107	30.7	32.5	68.1
	very well	105	30.2	31.9	100.0
	Total	329	94.5	100.0	
Missing	uncertain	14	4.0		
	99	5	1.4		
	Total	19	5.5		
Total		348	100.0		

Extent academic supervisor understands work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	12	3.4	3.6	3.6
	3	34	9.8	10.1	13.6
	4	79	22.7	23.4	37.1
	very well	212	60.9	62.9	100.0
	Total	337	96.8	100.0	
Missing	uncertain	7	2.0		
	99	4	1.1		
	Total	11	3.2		
Total		348	100.0		

How enthusiastic is industrial supervisor about project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all enthused	14	4.0	4.2	4.2
	2	29	8.3	8.8	13.0
	3	48	13.8	14.5	27.6
	4	89	25.6	27.0	54.5
	very enthused	150	43.1	45.5	100.0
	Total	330	94.8	100.0	
Missing	uncertain	14	4.0		
	99	4	1.1		
	Total	18	5.2		
Total		348	100.0		

How enthusiastic is academic supervisor about project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all enthused	3	.9	.9	.9
	2	11	3.2	3.2	4.1
	3	32	9.2	9.3	13.4
	4	104	29.9	30.3	43.7
	very enthused	193	55.5	56.3	100.0
	Total	343	98.6	100.0	
Missing	uncertain	2	.6		
	99	3	.9		
	Total	5	1.4		
Total		348	100.0		

Compatibility of supervisors' disciplinary backgrounds

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all compatible	9	2.6	2.8	2.8
	2	23	6.6	7.1	9.9
	3	59	17.0	18.2	28.1
	4	111	31.9	34.3	62.3
	very compatible	122	35.1	37.7	100.0
	Total	324	93.1	100.0	
Missing	uncertain	21	6.0		
	99	3	.9		
	Total	24	6.9		
Total		348	100.0		

Poor compatibility of backgrounds cause problems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	13	3.7	18.1	18.1
	no	44	12.6	61.1	79.2
	don't know	15	4.3	20.8	100.0
	Total	72	20.7	100.0	
Missing	99	276	79.3		
Total		348	100.0		

Differences between partners cause problems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	76	21.8	22.6	22.6
	no	199	57.2	59.1	81.6
	don't know	62	17.8	18.4	100.0
	Total	337	96.8	100.0	
Missing	99	11	3.2		
Total		348	100.0		

Partners worked before project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	204	58.6	58.6	58.6
	no	112	32.2	32.2	90.8
	don't know	32	9.2	9.2	100.0
	Total	348	100.0	100.0	

Which partner provides most leadership?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial	41	11.8	11.8	11.8
	Academic	257	73.9	74.1	85.9
	Equal	49	14.1	14.1	100.0
	Total	347	99.7	100.0	
Missing	99	1	.3		
Total		348	100.0		

Who coordinates/managers relationship?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial	21	6.0	6.2	6.2
	Academic	170	48.9	50.4	56.7
	Both	146	42.0	43.3	100.0
	Total	337	96.8	100.0	
Missing	99	11	3.2		
Total		348	100.0		

Personnel changes in coordinaton group?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	90	25.9	28.2	28.2
	no	229	65.8	71.8	100.0
	Total	319	91.7	100.0	
Missing	99	29	8.3		
Total		348	100.0		

Personnel change - at what stage of project happened?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1st	38	10.9	40.9	40.9
	2nd	37	10.6	39.8	80.6
	3rd	10	2.9	10.8	91.4
	4th	2	.6	2.2	93.5
	other	6	1.7	6.5	100.0
	Total	93	26.7	100.0	
Missing	99	255	73.3		
Total		348	100.0		

Personnel involved in change

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial	67	19.3	72.8	72.8
	Academic	17	4.9	18.5	91.3
	Both	8	2.3	8.7	100.0
	Total	92	26.4	100.0	
Missing	99	256	73.6		
Total		348	100.0		

Personnel change affect project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	32	9.2	34.4	34.4
	no	40	11.5	43.0	77.4
	not sure	21	6.0	22.6	100.0
	Total	93	26.7	100.0	
Missing	99	255	73.3		
Total		348	100.0		

How restrictive is project management?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all restrictive	93	26.7	28.2	28.2
	2	116	33.3	35.2	63.3
	3	88	25.3	26.7	90.0
	4	30	8.6	9.1	99.1
	very restrictive	3	.9	.9	100.0
	Total	330	94.8	100.0	
Missing	uncertain	15	4.3		
	99	3	.9		
	Total	18	5.2		
Total		348	100.0		

Gantt chart or list of deliverables/milestones for project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	144	41.4	41.5	41.5
	no	131	37.6	37.8	79.3
	not sure	72	20.7	20.7	100.0
	Total	347	99.7	100.0	
Missing	99	1	.3		
Total		348	100.0		

Encountered problems with project timescales?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	121	34.8	39.0	39.0
	no	189	54.3	61.0	100.0
	Total	310	89.1	100.0	
Missing	99	38	10.9		
Total		348	100.0		

Changed project objectives/research methods?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	174	50.0	55.6	55.6
	no	139	39.9	44.4	100.0
	Total	313	89.9	100.0	
Missing	99	35	10.1		
Total		348	100.0		

Collaboration agreement in force?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	124	35.6	35.7	35.7
	no	64	18.4	18.4	54.2
	not sure	159	45.7	45.8	100.0
	Total	347	99.7	100.0	
Missing	99	1	.3		
Total		348	100.0		

Collaboration agreement - who authored?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial partner	24	6.9	14.4	14.4
	Academic partner	16	4.6	9.6	24.0
	Both	66	19.0	39.5	63.5
	don't know	61	17.5	36.5	100.0
	Total	167	48.0	100.0	
Missing	99	181	52.0		
Total		348	100.0		

Collaboration agreement - asked to sign?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	96	27.6	44.2	44.2
	no	68	19.5	31.3	75.6
	not sure	53	15.2	24.4	100.0
	Total	217	62.4	100.0	
Missing	99	131	37.6		
Total		348	100.0		

Collaboration agreement - encountered any problems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	14	4.0	6.9	6.9
	no	126	36.2	62.4	69.3
	not sure	62	17.8	30.7	100.0
	Total	202	58.0	100.0	
Missing	99	146	42.0		
Total		348	100.0		

Asked to sign confidentality agreement?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	162	46.6	46.8	46.8
	no	151	43.4	43.6	90.5
	not sure	33	9.5	9.5	100.0
	Total	346	99.4	100.0	
Missing	99	2	.6		
Total		348	100.0		

How frequently joint project meetings held?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than once a year	27	7.8	7.8	7.8
	Once a year	97	27.9	28.0	35.8
	Quarterly	189	54.3	54.6	90.5
	Once a month	24	6.9	6.9	97.4
	More frequently than once a month	9	2.6	2.6	100.0
	Total	346	99.4	100.0	
Missing	99	2	.6		
Total		348	100.0		

Importance of email for communication with industrial supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	22	6.3	6.4	6.4
	2	22	6.3	6.4	12.8
	3	40	11.5	11.6	24.4
	4	59	17.0	17.2	41.6
	high score	201	57.8	58.4	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Importance of phone for communication with industrial supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	103	29.6	30.2	30.2
	2	58	16.7	17.0	47.2
	3	91	26.1	26.7	73.9
	4	52	14.9	15.2	89.1
	high score	37	10.6	10.9	100.0
	Total	341	98.0	100.0	
Missing	99	7	2.0		
Total		348	100.0		

Importance of F2F for communication with industrial supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	25	7.2	7.3	7.3
	2	34	9.8	9.9	17.3
	3	67	19.3	19.6	36.8
	4	85	24.4	24.9	61.7
	high score	131	37.6	38.3	100.0
	Total	342	98.3	100.0	
Missing	99	6	1.7		
Total		348	100.0		

Importance of email for communication with academic supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	20	5.7	5.8	5.8
	2	36	10.3	10.4	16.2
	3	68	19.5	19.7	35.9
	4	71	20.4	20.6	56.5
	high score	150	43.1	43.5	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Importance of phone for communication with academic supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	144	41.4	42.7	42.7
	2	50	14.4	14.8	57.6
	3	55	15.8	16.3	73.9
	4	48	13.8	14.2	88.1
	high score	40	11.5	11.9	100.0
	Total	337	96.8	100.0	
Missing	99	11	3.2		
Total		348	100.0		

Importance of F2F for communication with academic supervisor?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	2	.6	.6	.6
	2	8	2.3	2.3	2.9
	3	14	4.0	4.1	7.0
	4	58	16.7	16.8	23.8
	high score	263	75.6	76.2	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Attended any industry-academia networking events?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	156	44.8	45.1	45.1
	no	175	50.3	50.6	95.7
	not sure	15	4.3	4.3	100.0
	Total	346	99.4	100.0	
Missing	99	2	.6		
Total		348	100.0		

Encountered any communication problems with supervisors?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	94	27.0	27.2	27.2
	no	246	70.7	71.3	98.6
	not sure	5	1.4	1.4	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Communication problems - with who?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Industrial	47	13.5	46.5	46.5
	Academic	33	9.5	32.7	79.2
	Both	21	6.0	20.8	100.0
	Total	101	29.0	100.0	
Missing	99	247	71.0		
Total		348	100.0		

Quality of communication over time

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	improved	224	64.4	66.5	66.5
	worsened	25	7.2	7.4	73.9
	not sure	88	25.3	26.1	100.0
	Total	337	96.8	100.0	
Missing	99	11	3.2		
Total		348	100.0		

Communication problems between partners?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	37	10.6	10.7	10.7
	no	224	64.4	64.9	75.7
	not sure	84	24.1	24.3	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Extent project characterised by good management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	14	4.0	4.1	4.1
	2	34	9.8	9.9	14.0
	3	122	35.1	35.5	49.4
	4	127	36.5	36.9	86.3
	high score	47	13.5	13.7	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Extent project characterised by good communication

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	9	2.6	2.6	2.6
	2	27	7.8	7.9	10.5
	3	118	33.9	34.4	44.9
	4	126	36.2	36.7	81.6
	high score	63	18.1	18.4	100.0
	Total	343	98.6	100.0	
Missing	99	5	1.4		
Total		348	100.0		

Extent project characterised by mutual interest/need

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	12	3.4	3.5	3.5
	2	23	6.6	6.7	10.2
	3	74	21.3	21.5	31.7
	4	147	42.2	42.7	74.4
	high score	88	25.3	25.6	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Success of collaboration personally

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	11	3.2	3.2	3.2
	2	28	8.0	8.1	11.3
	3	79	22.7	22.9	34.2
	4	137	39.4	39.7	73.9
	high score	90	25.9	26.1	100.0
	Total	345	99.1	100.0	
Missing	99	3	.9		
Total		348	100.0		

Success of collaboration for industrial side

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	16	4.6	4.7	4.7
	2	40	11.5	11.6	16.3
	3	130	37.4	37.8	54.1
	4	117	33.6	34.0	88.1
	high score	41	11.8	11.9	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Success of collaboration for academic side

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low score	3	.9	.9	.9
	2	23	6.6	6.7	7.6
	3	104	29.9	30.2	37.8
	4	154	44.3	44.8	82.6
	high score	60	17.2	17.4	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Overall success

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	.6	.6	.6
	5	5	1.4	1.5	2.0
	6	9	2.6	2.6	4.7
	7	12	3.4	3.5	8.1
	8	16	4.6	4.7	12.8
	9	56	16.1	16.3	29.1
	10	41	11.8	11.9	41.0
	11	54	15.5	15.7	56.7
	12	79	22.7	23.0	79.7
	13	29	8.3	8.4	88.1
	14	11	3.2	3.2	91.3
	15	30	8.6	8.7	100.0
	Total	344	98.9	100.0	
Missing	99	4	1.1		
Total		348	100.0		

Extent enjoy research work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	not at all	8	2.3	2.3	2.3
	2	24	6.9	7.0	9.3
	3	54	15.5	15.7	25.0
	4	149	42.8	43.3	68.3
	very much	109	31.3	31.7	100.0
	Total	344	98.9	100.0	
Missing	uncertain	4	1.1		
Total		348	100.0		

Relationship between two parties improved or worsened?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	improved	180	51.7	52.0	52.0
	worsened	23	6.6	6.6	58.7
	not sure	143	41.1	41.3	100.0
	Total	346	99.4	100.0	
Missing	99	2	.6		
Total		348	100.0		

Student age group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	21-25	213	61.2	61.7	61.7
	26-30	78	22.4	22.6	84.3
	31-35	27	7.8	7.8	92.2
	36-40	14	4.0	4.1	96.2
	41-45	8	2.3	2.3	98.6
	46-50	3	.9	.9	99.4
	51-55	2	.6	.6	100.0
	Total	345	99.1	100.0	
Missing	System	3	.9		
Total		348	100.0		

Research Council

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	EPSRC	111	31.9	31.9	31.9
	ESRC	61	17.5	17.5	49.4
	NERC	74	21.3	21.3	70.7
	PPARC	16	4.6	4.6	75.3
	BBSRC	86	24.7	24.7	100.0
	Total	348	100.0	100.0	

APPENDIX 5E: Questionnaire Database 1 - Statistical results

Modes for 'Ordinal' Likert scale responses

Question no.	Description	N (no. of cases)	Mode
	Industrial motivations		
10ai	To extend their knowledge base	327	5
10aii	To have access university facilities/resources	309	2
10aiii	To have access to students	287	3
10aiv	To boost their sales/income	280	1
10av	To avoid in-house investment in long-term/riskier projects	265	1
10avi	To have immediate problem solving	301	3
10avii	To raise their profile within society	288	4
10aviii	To obtain prestige in marketplace	269	2
	Academic motivations		
10bi	To generate income	315	5
10bii	To find & work on real / industry's leading edge problems	321	5
10biii	To develop individual reputations	301	4
10biv	To see research being applied	322	4
10bv	To have an impact on society	295	4
10bvi	To expose students to real world problems	317	4
10bvii	To improve employment opportunities for students	320	4
10bviii	To have access to industry facilities	317	4
13	How well specified is the project?	339	4
14	How satisfied with project's progress?	340	4
15a	Extent industrial supervisor understands work	329	4
15b	Extent academic supervisor understands work	337	5
16a	How enthusiastic is industrial supervisor about project?	330	5
16b	How enthusiastic is academic supervisor about project?	343	5
18	Compatibility of supervisors' disciplinary backgrounds	324	5
24	How restrictive is project management?	330	2
39	Extent enjoy research work	344	4

Means for 'scale' Likert scale responses

Question no.	Description	N (no. of cases)	Mean	SD (standard deviation)
31ai	Importance of email for communication with industrial supervisor	344	4.15	1.23
31aii	Importance of phone for communication with industrial supervisor	341	2.60	1.34
31aiii	Importance of F2F for communication with industrial supervisor	342	3.77	1.26
31bi	Importance of email for communication with academic supervisor	345	3.86	1.25
31bii	Importance of phone for communication with academic supervisor	337	2.38	1.45
31biii	Importance of F2F for communication with academic supervisor	345	4.66	0.72
37a	Extent project characterised by good management	344	3.46	0.98
37b	Extent project characterised by good communication	343	3.60	0.96
37c	Extent project characterised by mutual interest/need	344	3.80	1.01
38a	Success of collaboration personally	345	3.77	1.03
38b	Success of collaboration for industrial side	344	3.37	0.99
38c	Success of collaboration for academic side	344	3.71	0.86

APPENDIX 5F: Questionnaire Database 2 Results - Motivations & Benefits

Students' motivations for doing project

Group $MOT_STU Student motivations

Category label	Code	Count	Pct of Responses	Pct of Cases
ACRESFAC	1	47	6.6	13.5
CONTCOLL	2	64	9.0	18.4
CAREER	3	75	10.6	21.6
INDEXPE	4	100	14.1	28.7
INDINPUT	5	12	1.7	3.4
INTRPROJ	6	33	4.7	9.5
KNWEXBTH	7	52	7.3	14.9
MONEY	8	137	19.4	39.4
NOMOTIV	9	44	6.2	12.6
PREVEMPL	10	8	1.1	2.3
RESAPPLC	11	96	13.6	27.6
SKLLTRNG	12	24	3.4	6.9
don't understand/can't categorise	98	10	1.4	2.9
no response	99	6	.8	1.7
	Total responses	708	100.0	203.4

0 missing cases;   348 valid cases

Benefits industrial institution gains from project

Group $BEN_IND Benefits to industrial institution

Category label	Code	Count	Pct of Responses	Pct of Cases
ACCESTUD	1	85	9.4	24.4
ACEXKNOW	2	139	15.4	39.9
ACRESFAC	3	65	7.2	18.7
LINKCONT	4	94	10.4	27.0
CHEAPRES	5	101	11.2	29.0
CURRAWA	6	22	2.4	6.3
DIFFPERS	7	15	1.7	4.3
EXTENRES	9	9	1.0	2.6
FUTROPPO	10	7	.8	2.0
INDFUTUR	11	17	1.9	4.9
ACAINPUT	12	38	4.2	10.9
POTLEMPL	13	52	5.8	14.9
PRESTIGE	14	79	8.7	22.7
PROUTPUT	15	66	7.3	19.0
PUBLICAT	16	9	1.0	2.6
QUALRES	17	36	4.0	10.3
RESINTR	18	4	.4	1.1
PROBSOLV	19	11	1.2	3.2
don't understand/can't categorise	98	25	2.8	7.2
no response/none	99	29	3.2	8.3
	Total responses	903	100.0	259.5

0 missing cases;   348 valid cases

Benefits academic institution gains from project

Group $BEN_ACA Benefits to Academic institution

Category label	Code	Count	Pct of Responses	Pct of Cases
ACRESFAC	1	119	13.3	34.2
ACEXKNOW	2	63	7.0	18.1
LINKCONT	3	144	16.1	41.4
CHEAPRES	4	4	.4	1.1
COLLAEXP	5	7	.8	2.0
EXTENRES	7	11	1.2	3.2
FUTROPPO	8	40	4.5	11.5
INDINPUT	9	25	2.8	7.2
MONEY	10	177	19.8	50.9
PRESTIGE	11	103	11.5	29.6
RESAPPLC	12	65	7.3	18.7
INTRPROJ	13	3	.3	.9
STUDEMPL	14	13	1.5	3.7
ATTRSTUD	15	30	3.3	8.6
STUDTRNG	16	12	1.3	3.4
INDPERSP	17	13	1.5	3.7
UPTODATE	18	9	1.0	2.6
PUBLICAT	19	15	1.7	4.3
PROUTPUT	20	4	.4	1.1
don't understand/can't categorise	98	10	1.1	2.9
no response/none	99	29	3.2	8.3
		-------	-----	-----
Total responses		896	100.0	257.5

0 missing cases; 348 valid cases

Benefits student gains from industrial side

Group $PBENIND Student benefits from industrial side

Category label	Code	Count	Pct of Responses	Pct of Cases
CONTNETW	1	99	10.7	28.4
ACRESFAC	2	156	16.9	44.8
SKLLTRNG	3	102	11.0	29.3
ACKNWEXP	4	63	6.8	18.1
CAREER	5	21	2.3	6.0
INDEXPE	6	173	18.7	49.7
INDPERSP	8	25	2.7	7.2
INDINPUT	9	57	6.2	16.4
MONEY	10	61	6.6	17.5
PRJMGMT	11	36	3.9	10.3
RESAPPLC	12	35	3.8	10.1
PRESIND	13	11	1.2	3.2
TRAVCONF	14	15	1.6	4.3
CONFID	15	4	.4	1.1
BROADSC	16	4	.4	1.1
don't understand/can't categorise	98	28	3.0	8.0
no response/none	99	35	3.8	10.1
		-------	-----	-----
Total responses		925	100.0	265.8

0 missing cases; 348 valid cases

Benefits student gains from academic side

Group $PBENACA Student benefits from academic side

Category label	Code	Count	Pct of Responses	Pct of Cases
ACAINPUT	1	111	12.0	31.9
CONTNETW	2	72	7.8	20.7
ACADEXPE	3	56	6.1	16.1
ACKNWEXP	4	119	12.9	34.2
ACRESFAC	5	65	7.0	18.7
INDEPTH	7	15	1.6	4.3
CONFID	8	12	1.3	3.4
CONFPRES	9	24	2.6	6.9
ACADTHKG	10	23	2.5	6.6
FLEXIBIL	11	39	4.2	11.2
SKLLTRNG	12	260	28.2	74.7
PRJMGMT	13	54	5.9	15.5
MONEY	14	6	.7	1.7
RESAPPLC	15	8	.9	2.3
MOTIV	16	11	1.2	3.2
don't know/can't categorise	98	17	1.8	4.9
no response/none	99	30	3.3	8.6
	Total responses	922	100.0	264.9

0 missing cases; 348 valid cases

APPENDIX 5G: Responses to Open-ended Questions

Qu. 12a: "Have there been any unexpected benefits from the project? If Yes, please describe briefly what the benefits were":

ID	**Travel/conferences/external courses**
TAKI	Travel bursary for international conference
SMAG	A trip to the US to present work at the sponsor's factories, A visit and 2 presentations at a conference in Berlin.
OGOO	Travelling abroad for a couple of conferences
MONE	Ski trip to French Alps for a conference
VMAL	Ability to be able to present research at both scientific and industrial meetings. Therefore getting myself known in both areas
GPRE	one field trip to their research station in Plymouth, one trip to a conference in Sweden.
CHIL	Funding for conference in Florida for both myself and another PhD student that we collaborated with but who does not have a case award with them
NSTE	I have been on a course to learn more about diesel fuel injection systems and have attended topic related conferences.
AHUN	Trip to Vienna
DCAR	Travel throughout the company to Europe
JBRO	company conferences
ISHA	I didn't expect to organise an important conference (EngD Conference 2003) and now I have that experience under my belt.
ISCR	Annual trips to exotic locations for the conference of the International Association for Impact Assessment.
RMCG	I have the opportunity to travel across the world to visit customers and attend conferences / events.
TSIN	a large budget has been set aside for travel purposes
DKIN	Actually, not yet, but I may get to go with my industrial supervisor to a conference.
AFRI	I attended a [RC] Grad school which was a great experience and I have been invited by the American Chemical Society to present my work in California.
JKEN	I got a place on the annual beam trawl survey of the Irish Sea which I feel is good experience for my future career
EHOB	Been away on courses that have helped my project intellectually/practically and given me skills in social/workplace interaction, confidence to present work etc..
KTAY	I'm in Hawaii right now! I'm working at the US branch of [IND] for up to a year and negotiated a month off to go travelling, through the Hawaiian islands.

ID	**Fieldwork/facilities/equipment/data**
CEMB	There is the possibility that I may be able to make use of boats already in the West Coast to do survey work.
JCOO	Industrial sponsor to pay for field trips.
SHAD	Have possibility of using [IND] technology – equipment, modelling programmes. use of [IND] samples from drilled wells
JBIR	Opportunity to collect some data from secondment to turn into case history for thesis
NHARR	Access to international facilities and information
LDAV	If (still not confirmed) I get lap top.

ID	**Commercial benefits/patents/research application**
DMILL	a heat seal packaging patent and probable revenue
LYOU	Possible commercially useful processes for bonding unstable materials
SMAG	A patent will be applied for...
JCRO2	Development of new assay for use in industry
LHER	I have helped the industrial partner correct bugs in their code.

ID	**Greater understanding/knowledge**
PLOW	I've found out a lot about the real motivations of research institutions.
HTEW	The breadth of experience of my colleagues
ESTA	I have learnt a great deal about the highs and lows of science as a business.
APER	I got experience of scale up, and actually enjoyed living in Kent
SWIL	I gained an insight of how different projects are managed simultaneously.
LBRA	I have found it very difficult to make the aims of the PhD and sponsors commensurate but this has actually been a strong learning tool in that this echoes some of the issues in the project that I am working on regarding collaboration
MBOW	Opportunity to carry out failure investigation jobs for the Company - extended knowledge beyond that of the project alone.

ID	**Industry support**
NHUT	The sponsoring company has carried out a lot of time consuming and technically difficult analytical work
RPOR	My industrial supervisor has been excellent and is a real source of help on the project. This was not expected.
HCOL2	The industrial sponsor allowing me a large degree of academic freedom in my work.
NBRO	sort of: I thought that it would make my research easier to do, and it has at times but i did not expect to make close relations with the sponsor. the length of time and extent of involvement means that you work closely with some people so that they become colleagues rather than sponsors.
RQUI	Contact with industrial sponsors kept this student sane!! Coming from an industrial background, have found the laidback approach of university very hard to come to terms with initially. Was very dissatisfied with level of progress, and struggled to get supervisor to understand my concerns. Regular contact with people in "real world" of work helped me stay on line and less inclined to give up.
KKEL	I found that my industrial supervisor and one of his colleagues were in fact better supervisors for me than my academic supervisor. I found them easier to talk to and liked the industrial perspective which keeps the project a bit more down to earth and useful!

ID	**Industrial placement**
MFUN	Having the opportunity of being involved in the case-partner's projects/ consultancy work to a greater extent that assumed at the outset. Partly down to chance in terms of relevance of the projects that the case partner has been involved in/ bids that have been won.
HNOB	I have moved to my sponsor's lab and been given the opportunity to become part of the team. I have also found that for my particular project the opportunities for travel and the expansion of my knowledge are very large, mainly due to one of my supervisors.

ID	**Career**
TJOY	From a personal point of view I would say the personal development and wider employability that the Exec MBA programme provides over a strict theory focused PhD.
CSMI	A job at the end.
SABE	Possible opportunity to work at industrial placement after finished PhD
PALL	It has provided clear insight into where I would like my career path to lead.
EPRO	Intend to complete an internship at my CASE sponsors related to my project.
EINN	I have found an area of interest that I hadn't imagined. I now know what I want to do on completion of the PhD

ID	**Training**
PGOS	Better appreciation of psychological issues associated with odour nuisance, importance of social as well as technical solutions.
EREI	The MBA has been much more useful than what was thought. There are not two separate parts to the EngD, the management section has helped develop the research for a much more rounded view.
FBUT	Every year, for a whole month I go on a work placement for the industrial partner working on projects for them, this has raised my profile in terms of employability, knowledge and networks.

ID	**Contacts/Collaboration**
JHOL	We have established a London Unions Research Network linking all academics and trade unionists in London working on research in this field.
DSHO	Meeting more people within the industry
SCOY	Inter-departmental collaboration with the chemistry department.
AFOR	[IND] are associated with the COMIT Faraday Partnership enabling myself to become a Faraday associate with the benefits of attending academic/industrial closed meetings with opportunities to give presentations on my research to both academic and industrial experts that I wouldn't normally encounter.
NJEN	Additional collaboration with University Wales College Medicine Funding from [IND] to develop and pilot research instruments.
JCAR	Having access to two supervisors who know different people has resulted in many opportunities to take studies in a new direction.
TBUT	My work for the museum brought in contact with an artist who has had a profound effect on my research plan.
DCAR	...meeting people quite high-up in the company.
TKIR	Friendships with my fellow students (I am 46)
RCOO	A strong friendship and research base from being close to other EngD students.

ID	**Other**
BDOB	The money has worked out to be quite helpful
YIDA	new ideas for more CASE studentships

Qu. 19a: "Are there any differences between the industrial and academic partners which cause problems when carrying out or reporting on the project? If Yes, please describe briefly":

ID	**Different opinions/views on project**
SKOM	Different views of research questions, methods and outcomes. Completely different view of the world in general!
YIOA	different objectives cause conflict, but I decide ultimately!
TKIR	At the start, there was a large difference between the Industrial and Academic view of the project with regard to the aims. This caused some pain early on.
TDEW	Differences in desired project outline, progress and outcome
JFOC	Generally we have a good agreement. There have been occasions where the industrial partner wanted to go one direction and we the other, although we solved these issues quite amicably.
LBRA	But this is more limited than would be expected (related to goals/ priorities of the research)
CCOR	Their ideas for future work tend to differ which can lead to problems and the enthusiasm for some work also differs between them.
RQUI	They seem to have very different ideas as regards to where my project is going, and a definite frostiness between the two means communication is difficult and I often play piggy in the middle.
JBIR	very different ideas on how to carry out some of the standard areas of work in this field - difference between industry standard and academic state-of-the-art.
ABAZ	Different focus on specific problem solving or broad brush ideas.
ALOC	CONFLICTING IDEAS ABOUT HOW TO MOVE FORWARD
WLEW	sometimes want research in different areas.
SPAR	Minor problems only, although their research backgrounds overlap quite well, they do want to pull the projects towards their own specific area of interest. The best way to reconcile this is to refer to the specific outline of the grant and stick to it!
NON4	Different opinions on topics to be researched...
PLOW	Can't agree on a contract that allows me to carry out my research as proposed
JWIG	everyone wants something different and wants to chip there two penneth in, its bad enough

	when your trying to negotiate two academic supervisors, add in someone from outside and maybe one or two of their teams ideas and you have a stack of suggestions that complicate matters as you try and work out what you want and say why that is. This can be a particular problem if the industrial supervisors start trying to alter the project once your about to commence the research.
CWAR	Sometimes they have different points of view about what is important...
SMCC	...Each has a different focus on what is important, which is to be expected.
SPRA	...Also my two supervisors have different perceptions of what is possible and certainly this was confusing for me initially- 3 lots of views to try and take on board.

ID	**Lack of interest/input from industry**
MBUR	My academic supervisor and I believe that my industrial supervisor should have more input than he has recently delivered and seems to have lost interest in my projects direction
MMCK	industrial supervisors do not give feedback on reports
SDEN	Have very little contact with the industrial supervisor

ID	**Difference reporting styles/requirements**
CHIL	differences in format of reporting and use of stats
AYOU	Perceived differences between academia and industry with regards to the way in which data should be interpreted
OALL	Reports in chemistry take a very different approach to biological reports which have made it difficult to write my thesis.
FWOR	Differing expectations and requirements as to report length, style, contents etc.
TNON	every partner prefers own style. might conflict. you have to prioritise.
NON4	...different styles of writing
SMCC	But only because they each require a different approach and language...
FBUT	Difference of Approaches, which are overcome through discussion and communication
TBUT	Different ideas about what constitutes a report...
RCOO	Different approaches expected...
CWAR	different points of view ...about the way data should be interpreted or reported. But I think that could happen between 2 academic supervisors as well!
SKIR	Basically if the report do not show a significantly positive reflection on the companies produce then there is a willingness to either not report it or gloss it over, this of course is unacceptable to myself and academic supervisor who are keen to report ever results.
MRIM	Two case study field reports were produced. One outlining positive aspects of partners work, second was more critical. The second report caused something of a storm which has subsequently been iron out (to a degree). The 'status' of the report was cited as the cause of the misunderstanding by the partner, i.e., it was unclear what the purpose of the second report was and who it was intended for.
SELV	Industrial focus is applied academic reporting naturally is more theoretically based. It is challenging to fulfil both criteria adequately!
SETH	Only occasionally. Industrial supervisor wants more applied research and lots of reports.

ID	**Time/work pressures from industry**
AFOR	The deadlines for industrial work are more strict than for my supervisor such as copyright clearance for work to be presented at conferences. Industrial partners would like me to work a month in advance whereas my academic supervisor is happy for me to work up until the last minute. This is not really a problem but is a definite issue.
RCOO	Different time pressures and expectations.
OSIM	Industrial sponsor hasn't participated in similar scheme before, and can be impatient for results.
JOLL	Industrial supervisor i think sometimes forgets that i am a student and not an employee as he keeps expecting me to start particular work at set time to save him being hassled from others overseeing the project funding, without really giving me much time to work on them especially on learning the basics for my literature review. Sometimes it seems that my supervisors running the project and not me. No problems with academic supervisor as the project is mine to run

SPRA	Only in as much as CASE partner want more than can be achieved in the time, and it is not that straightforward to produce these results.
HBEC	Differing expectations due to industrial partners not fully understanding nature/length/depth of a PhD - thus expecting output very quickly, and requiring extra work/input from me which interfered with PhD work - but this was resolved with help from academic supervisor
KCOT	Industrial sponsor fails to understand the extend of work, for one person, that he would like performed

ID	**Industry want simple results / academic want more**
EPAR	*[X]* want very broad conclusions but research in this field takes place in very well defined conditions so broad conclusions cannot generally be made.
ESTA	Not a major problem, but Industrial supervisors look at my PhD as a product and often are not in why some of the science doesn't work, but just interested in can I get round it without knowing the whole picture, as this delays product development.
LYOU	Industrial partners do not appreciate the need for a theoretical basis for the research. They only require a solution to a problem. Industrial partners have requirements to meet and these usually require testing to a certain standard but they are not generally interested in understanding why something works only that it does at a required level.
DSHO	It is often difficult to satisfy both the academics who want pure high standard research and the industrial who what something they can implement and use easily
TJOY	Industrial sponsor is interested in research findings and suggested solutions only, whereas Academic supervisor is more concerned with the methodology used to arrive at findings/decisions and seems to have little understanding of the technical aspects of the project. Hence, it can be a challenge to provide 1 report that fully satisfies both.
BKOH	industrial side is not really interested in theoretical questions
VHAN	Academic supervisor ensures high quality output, Industrial supervisor ensures output is policy relevant and understandable
PGRA	Academia is much more interested in solving the "why" issue, where as Industry is more concerned with "How". A PhD is more of a "why" degree, and the temptation to focus on the How is a quite strong diversion.

ID	**Publication/confidentiality issues**
MLAT	industrial partners may have issues with publishing of papers due to wanting to develop a product from my results.
JKEA	Any results to be published or presented must first go through the industrial partner and they can delay publication (although they have not done this yet)
MBOT	Potentially, if there was a new discovery that would be beneficial to my industrial supervisor, I would be held back in publishing this.
NON3	Some work may end up being patentable, and hence there is a difficulty in publishing and reporting on it. On the academic side, we'd prefer to publish.
JANS	Publishing could be an issue, my industrial partner has to approve publications, if they don't approve publication can be delayed by up to a year (its in the contract)
RPAT	Industrial Secrecy of some oil fields
RDAY	Knowing what we can publish and what must remain an industrial secret.
HTEW	Industrial sensitivity of some aspects of the project, confidentiality in reports etc.
RCUR	Also where to publish is an issue - though publications with industrial clout don't tend to have good impact factor which is all the academics tend to take into account.
RPEA	Some information in the project is of a confidential nature which does cause a degree of difficulty at times when reports need to be issued at university.
LGRA	Not a major problem, but due to sensitivity of some material industrial partner needs to OK everything prior to use
MCAL	There are various other companies that each institution works with and have NDA's with and often we have to be careful what is said about certain areas of research/collaboration
PALL	My research at [IND] is of a confidential nature, while my academic supervisor does not have the necessary clearance to see some of the results and data that i produce for [IND]. This means an abundance of time is spend switching between models trying to explain problems without actually showing to much detail.

ID	**Ind. financial v academic res. view**
VMAS	Inevitable differences between academic research and Industrial financial gain
PARR	Slight conflict of interests. I think the industrial partner is looking at many things from a financial point of view and this is not generally the academic view of research
PHUG	Also, the sponsors are mainly concerned with the commercial aspects of the project (how can it be used to make money?) which is sometimes at odds with getting a PhD finished.
GDAV	Industry only interested in cost saving projects, not overly interested in long term research.

ID	**Discipline**
PHUG	As engineers it is often difficult to explain the engineering aspects of the project to the sponsors who are chemists...
ABRU	My supervisor went on maternity leave and I have another supervisor who is just as good but not as academically minded - more practical and I felt had less understanding of the ethics of methodological design and implementation then my other supervisor would have had.
PSHE	Partner has very limited geographical research skills or resources.

ID	**Financial**
KHEW	Academic partners appear too desperate for money. Industrial partners don't appreciate difficulties of performing research in badly funded institution
RCUR	Mainly to do with availability of cash leading to parts of project being cancelled.

ID	**IPR/ownership**
MRAY	There was a big disagreement over the intellectual property rights which was initiated by the college
NBRO	ownership is an issue for all

ID	**Workload**
TBUT	...industrial partner snowed under with work and needs help with things not strictly relevant to my project
ASIM	...Very busy people - Many commitments
GDAV	Academic supervisor, far too busy lecturing to be overly interested in research.

ID	**Geography**
RHIC	Because I'm based at the other end of the country from my university I have problems when I have to return for meetings, courses etc. and the university makes little effort to help me out.
ASIM	Transatlantic!...

ID	**Other**
CFOS	Industrial supervisor thinks I should drop things if they are not working, while my academic supervisor is much more concerned with me producing a piece of work that is thorough enough to pass a Viva.
CSWA	Management style – *[IND]* (industry) Personal relationships - traete as a 'worker' rather than as a partner
JMOR	The motivation for each partner are different. The industrial partner is constantly striving to account for/deny health and safety problems, and the academic partner is striving to highlight these problems.
HCOL	The academic can be dictatorial and inflexible whereas the Industrial collaborator would prefer that there was a little more freedom to adapt the work depending on the experiment outcomes
EATT	Academic supervisor pays more attention to the fact that ideas and experiments have to be linked to pre-existing literature and therefore 'off the wall' ideas are harder for me to link to literature.
AWAL	Perspective occasionally causes problems. The academic sometimes tries to sell his own branch of research (which is not the same as mine) to the industrial. The industrial supervisor sometimes cannot see the long term necessities.
MRAY	I have many problems with the administration department at [UNI], which has had massive implications on my finances.

RPAT	Some of my research fits into another departmental initiative that is sponsored by competing companies.
RMCG	The industrial supervisor is bias towards research being carried out in industry that will provide base data for the academic research
GMCG	The industrial supervisor is involved in the project I am assessing, therefore perhaps less impartial about its results

Qu. 36: "Please comment on any other problems which you have encountered in relation to I-A collaboration that have not been covered earlier":

ID	**Communication problems**
AJOH	They don't really contact each other
ALOC	Industrial supervisor takes about 6 weeks to answer emails
JOWE	...industry partner's liaison or lack of it with the ESRC... *[late year end report]*.
MFUN	...communication problems... at the outset with the case partner were probably not so much a problem as... the case partner's interest understandably is greater towards the end of the PhD when the results are coming in, rather than at the beginning when a lot of time is spent on literature review... However, it would have been useful to have more input and discussion from the case partner at the beginning concerning research questions and methodology.
NON1	...lack of contact with my official supervisor. However, this has been solved by drawing on support from another (more relevant) member of staff
RPOR	It is always good for the supervisors in both industry and academia to have ALL met to discuss the project. No supervisor from the institution that I am registered has ever been to see the industrial partner. This is not be allowed to occur.
VBOD	in the first two years spent a lot of time (months) waiting for the company's replies to my emails
VHAN	Not so much a problem but explanation of jargon by both supervisors has been very helpful for the three of us.
CWIL	I have never had any contact, what so ever, with our industrial collaborators. Partly due to their lab moving to the states at the start of my PhD, and partly as they seem to have changed their interests...
NON3	Motivation on the part of industry was not really revealed until the 3rd year. I guess I didn't ask early on, but I think they could have communicated why they wanted the project done much more clearly and completely at the start. It would have helped me understand the task a lot better from the beginning!
TJOY	As a general note: Coming from an industrial background into academia for this EngD, I have always disliked the use of academic jargon from my academic supervisor (frameworks, methodologies, etc) and more so its extensive use in academic journals and papers, which seriously impacts their usefulness to industry as engineers simply do not want to waste time deciphering them into straightforward terms they can understand and apply.
GOWE	Took a long time to receive my industrial sponsorship money - due to some form of communication breakdown somewhere along the line.

ID	**Conflict/change of interest**
KARF	...industrial partner is somehow indifferent to the project's well being, apart for parts of it that he can use for his own benefit.
KTAY	The focus of the industrial partner changed during the first year and consequently my project now has little relevance to the organisation...
NJEN	Low prioritisation of theory from Indus. Sector
TJAC	Industrial sponsors are only interested in a very small proportion of the results that will be generated by this project causing them to show little enthusiasm. Problems ...possibly due to this are that i am still waiting for my industrial grant and the department is still awaiting payment for new equipment despite extensive prompting
VELL	Conflicting Ideas

ID	**Timescales**
SELV	Timescales and priorities are different...
FLEA	It has been difficult at times to get sponsor to deliver promised help (resources etc) in a timely fashion... from someone within the company other than my supervisor. Supervisor has been helpful in chasing up, but this delay has resulted in difficulties in planning etc.
CFOS	They *[company]* were very slow in getting the necessary information to me...

ID	**Workload of supervisors**
HBEC	Also occasional communication problems due to extreme workload of industrial supervisor
JHEI	...pressure of work on the industrial partner, who has lost staff from his department & had extra work given to him.
OGOO	It has been quite difficult to get the two parties together due to their busy schedules
DCAM	Arranging times to meet as industrial collaborators are busy

ID	**Industrial changes**
CHIL	...my industrial supervisor left *[X]* during my first year ...now I have to try and liaise with people in *[X}* who aren't directly related to my project ... they don't want to help
FWHI	...loss of the former manager of the industrial partner... now little input, if any, from that partner although clearly this leaves me with a great deal of flexibility in my research
KMCL	My industrial supervisor has been on maternity leave twice during the project... only contact that I have had with the authority has been on my initiation.
LGRA	Internal changes within industry not made known till after event and then only to a limited extent. Initial contact re-deployed leaving unanswered e-mails for a short time (1 month) during transition period
LBEL	The original industrial sponsors... bought out by *[X]* in the first year of this collaboration. Since then my new industrial supervisor has assured me they will continue to support financially although they can be of little help with the actual project (as they have no experience of this field).
ISCR	I'm on my third ind supervisor - other 2 left *[X]*... Not much continuity, though all came from the same team... Loss of first supervisor was a shame because he had set it up, and was the most enthusiastic and interesting of them
JFOC	One of the original partners in the project, where I was to spend the allotted three months of each year working, went bankrupt half way through the second year. This was initially worrying as I did do some important study here that could not be easily carried out at my academic institution.
EINN	Changes of industrial supervisors is unsettling but I am allowed to guide my project so there was no major disruption
FBIS	The withdrawal of the provision of complementary medicine services by the industrial partner (in year 2 of my studies), while unavoidable, has meant that the applied side of my research has less immediate relevance or importance for the industrial partner. The problems which this withdrawal created (e.g. lack of research participants, some redesign of studies necessary) have been suitably resolved (through good communication between industry and academic partners), and overall I feel I have learnt a lot from this experience.
SYEO	there has been three changes in industrial supervisor due to them leaving or being sacked.
RCUR	I have had 2 industrial supervisors throughout the project and though the main supervisor (he who pays but I have little contact with him) has stayed the same, the secondary supervisor (generally the more helpful one) has changed 3 times. This has not been a problem, though it highlights the instability of management structures in the workplace – poss. another benefit of working within industry!

ID	**Scoping of project (industry)**
HBEC	Initial project proposal was far too ambitious for a PhD and have been restricted in making changes by policy requirements of industrial organisation.
KTAY	Also, the original design of the project was unworkable due to internal politics within the industrial partner organisation...

ID	**Problems with Industrial supervisor**
CFOS	Industrial supervisor has shown little or no supervision of me.
RHOP	industrial supervisor has no interest in meeting me at all. I have offered numerous times to present my work to him, but he never answers me.
JMCL	Clash of personalities between myself and industrial supervisor. My industrial supervisor was decided upon after my beginning the project and I do not feel that personalities were taken into account in this decision.
JNOS	I feel the industrial partner is completely disinterested in me and my project. I feel like an item in somebody's intray and when they take up post, they realise that this project is appended.
KSAN	industrial partner not interested in the academic outcomes and expecting very quick project turnaround
NHUT	The industrial partner is unenthusiastic about the project despite reasonable successes as measured by publications
GDAV	Industrial (Supervisor) not interested in research as he has inherited this project and it is not his field.

ID	**Problems with Academic supervisor**
GAND	There appears to be more tension between my two academic supervisors than there is between my industrial and academic supervisors.
APER	snobbish attitude of academic supervisor towards industry
GDAV	Academic Supervisor not prepared to travel to company, and not interested in project unless Eng D student hassles him... The project has been very one sided very biased towards industry this far despite students attempts to change this it has been very difficult due to lack of support from academia

ID	**Administration / Funding**
APRO	...lack of formal guidelines in relation to the way money is received from the sponsor
CJOH	transfer of funds - maintenance and fees passed from industrial partner to academia, late payment and academic administration
PSHE	Changes to funding mechanisms used by the industrial partner have caused some confusion.
SPAR	...problems with industrial stipend payments which are issued from the university finance office. Both sides seem to have very complex procedures which slow down/stop the receipt of these cheques... often takes months of telephone calls and emails from myself and supervisors to get this sorted out. Not being based on campus also makes the resolution of this problem more difficult...
MRAY	...massive problem with the administration department at the college, who don't seem to understand how industry works! ...gross mismanagement within the administrative departments at the college.
LMOO	Delays in obtaining first year CASE support fund due to contractual bickering between *[X]* and the University.
RPOR	No contract has been signed by either side and so it has been a real battle for me to receive CASE money. This should have been sorted out before the project started and should still not be unresolved 14 months in.

ID	**Different opinions / Expectations**
DLEM	...differing opinions on direction... Academia wish to produced simplified models - industry wants to work with real life materials.
HCOL	Friction between Academic and Industrial Research Scientist - differences of opinion about how and what research should be carried out.
HARN	...industry partner wanting to advertise research findings more quickly, and widely, when still in too early a stage of the research to want to report concrete findings
SKOM	Practice world wants quick-fix answers to their practical, everyday problems, but qualitative sociological research has different goals.
AROG	It was hard at first to manage meetings as the supervisors came from such different disciplines, the industrial sponsor was keen to move the project forward prior to myself and my academic supervisors feeling it was appropriate. But this doesn't happen now, it was just

	a natural progression not really a problem
MLIE	Pleasing two masters can get a bit tricky but when one accepts that at different stages the requirements of one takes precedence over the other, it can be overcome, though it may mean that the research proceeds in less ideal circumstances than if there were only the one master
ASIM	Some disagreement on the future of my own and connected projects
MBOW	At the start expectations varied between the two, leaving me stuck in the middle (mainly due to it being a new course)
ABAZ	Bit unsure of the direction and I feel the industrial and academic directions are diverging

ID	**Multiple partners/collaborators**
MCAL	We are working with a student based at our industrial partner and also some at another university… we work in different institutions… It is sometimes hard to collaborate without being there in person which is often hard to achieve.
SELV	I also deal with more than one person at the industrial sponsor's head office and there are internal tensions between different departments that have caused problems at times.
JAND	I have three supervisors and coordinating times that all three are free in order to meet has been problematic in the past.

ID	**Confidentiality / Intellectual Property/ Collaboration agreement**
NBRO	…it sometimes feels difficult to ask for things from the industry side as I sometimes have a lot to ask of them… get the sense that they feel that they are being researched and this makes them a lot more cautious about what they say and the implications that this might have for them/their job
EEDW	Work that was to be presented at a conference did not get through company intellectual property clearance in time. However the problem was overcome by removing any references to the company from the poster
LYOU	Currently issues are being discussed with reference to IPR and Confidentiality due to the lack of any formal agreement being drawn up at the beginning of the project.
TKIR	There is no collaboration agreement. This is a long and sorry saga of incompetence which depresses me if I allow myself to think about it. Because my work is commercially sensitive there are issues with publication and I will only publish 1 paper out of potential 3. An EngD is aimed at Industry to prepare students for early advancement into senior roles, and publication may raise serious confidentiality issues. IP ownership is also a concern.

ID	**Geography**
ODOU	My industrial collaborator is a long distance from the university… I'm not sure how much time I will actually spend there, probably very little.
RPAT	It is more difficult for students projects whose sponsors are based abroad to spend time at their companies, as no extra funding is allowed for travel etc. The EngD structure is still relatively new (unknown in the USA) and the differences between the EngD and a traditional PhD in terms of the thesis, examination are still unclear on both sides.
SYEO	I work in bath, my uni is in [X] and my supervisor is in [X] (this makes life very difficult at times and i feel very isolated) as i have no one working around me on the same projects.
GDAV	…Distance has been a huge issue as neither supervisor is prepared to travel…

ID	**Other**
LBRA	…the element of collaboration is as not as high as I had expected it to be and it has been tricky managing such a complex project as my first experience of empirical research
CWAR	…because my industrial partner is also quite academic based *[gov. res centre]* …I think that many of the potential problems just do not apply here.
TMOR	Acting as a full time resource in an industrial department for the initial 6 months of the project made it difficult to gain the correct division of time between industrial and academic needs
JAND	Also, it would be useful to get input from other academics in other disciplines (e.g chemistry/microbiology) that is not that easy to get.
DCAR	If the company has not had an EngD student before, there is not so much guidance from the University as I feel there should be.

Qu. 41: "Have you any other comments on the process or experience of I-A collaboration?"

ID	Supervisors collaborated before
ABOW	I was fortunate because my industrial and academic supervisors had worked together on a number of other research projects before.
DEGA	I am lucky as the industrial and academic supervisors know each other very well and have worked together before. They therefore know what they might expect of each other in a professional capacity. I have felt very welcome since I started.
TKIR	I was lucky, my Industrial supervisor has supervised many PhDs, but other students have suffered by because they Industrial supervisor had no research experience and the Academic supervisor no Industrial experience.
KTAY	University and [IND] already had a long standing research agreement when I arrived, so it's been ideal.

ID	Disciplinary / Culture/ different styles
AJOH	I think it works better in non-social science subjects
CMAC	There seems to be a strong tension/large divide between academic work and practical problems. For a fresh-faced undergrad straight into the PhD, CASE work can be immensely challenging to begin with. Doing practical industry-academic work seems to lay bare much of the chasm between the ivory tower of academia and the adobe hut of practice! I personally found this uncomfortable to begin with, but ultimately very rewarding as the project has progressed -- and the tension between theory and practice has become a central element of my research.
CJOH	they are both very different structures and cultures - it has been extremely useful to see how the two differ and to get an understanding of what is required by industry before entering that market-place
WLEQ	My case project is more an example of academia-academia relationship. 'Industry' in the marine ecology and fisheries field doesn't vary much from research in the academic field. *[gov. res. centre]*
LBRA	I think depending upon your background and the project it is a very challenging and potentially confidence undermining route into research unless there is a high level of collaboration or support
WBEN	My second industrial supervisor completed a PhD approximately 4 years ago; I am sure this has made a big difference in terms of understanding the process & the outcomes
NON1	Getting a focus was one has been a challenge. It involved getting my head around what was going on at [IND] and then trying to match some element of this with academic theory.
PALL	The agreement between the two required that I attended a summer placement each year with [IND]. This was all very good in theory but I found that much time was wasted converting myself from university mode to industry mode (by this I mean different computer programs/systems, changing specific problems, etc.)
MLIE	Two different styles required i.e. reports to industry very different to writing academic chapters - easier to write the former, which can interfere in the writing of the latter.
SKIR	I have found that the two are based so differently in expectations and philosophy that balancing the needs of both is near impossible. Especially when working in a company that doesn't have a research department and therefore understanding of academic procedures is lacking.
HBEC	...benefited from my experience working for a social research organisation prior to the PhD - would have found it much harder without the negotiation/professional skills I gained there.

ID	Understanding
VHAN	The industry supervisor understands and has supported the 1st year focus on academic issues; methodological training, theoretical background etc based at uni, this forms the basis for the 2nd year which will involve case study work at the council, and potentially outputs for industry use. The final year has been agreed as 'my' year for writing up using both academic and industrial resources.
MRIM	There are probably always instances where prior clarification of some roles/responsibilities are not a realistic possibility - they must be responsive. This can result in misunderstandings. Fortunately, I feel that these have been dealt with well in the case of my CASE, especially on the part of the academic supervisors.

TBUT	...takes a few months for all partners to understand what is expected/going on. Some extra time for the programme/award might be sensible.
JEDW	Its helps when you have industrial/academic supervisory staff that understand how the "other" sides works and therefore what drives the research.

ID	**Flexibility**
RCUR	Industrial supervisors have given me a lot of freedom, though they are poorly briefed from the outset and so tend not to be aware of why I am away on courses, the structure of the EngD etc - they should be more aware of the researchers needs, requirements academically etc.
PGOS	Industrial sponsor was quite happy to let me lead the project (unusually, I developed the proposal) which suited both parties.

ID	**Communication**
JWIG	the communication between myself and the external body has probably deteriorated due to main supervisor at industrial place taking a sabbatical, and the fact that i feel like my research is at the bottom of their priorities - though may be I should have made more frequent contact.
SPRA	In my case there are maybe too many cooks- two academic supervisors and two case supervisors. Not all communicate with me let alone each other!

ID	**Timescales**
EPAR	Industry have very strict deadlines to meet their paperwork requirements that do not always fit into the timescale of my research. Less flexible with their timescale than university which can lead to problems.
RMCG	Industry tend to want results now and not to the level / detail required for a PhD project

ID	**Market**
ACLA	The collaboration is governed by the market and how well the industry is doing at the time of the project]
TNON	market issues, e.g. market downturn, acquisitions,.., effect collaboration

ID	**Size of company**
TJOY	The [company] is too large and fragmented for a single research project to have any dramatic effect on their operations and the sponsor is probably too busy in his day-to-day work to provide the optimum level of collaboration for such a project.

ID	**Conflict/Change/lack of interest**
JLEE	Process is very much subject to the industrial partners interest. This interest can vary significantly over four years.
NHUT	It is disappointing that the industrial partner does not seem interested in assimilating the technology they have paid to developed into their laboratories.
RING	In truth, there has been very little industry input into the project - they have given me and my academic supervisor free rein to pursue a standard PhD with the exception that they provide some data and are interested in the final outcome of the project. This is contrary to how I expected the CASE scheme to work, but I am happy with how it has worked out as I have more freedom to pursue my own ideas and less travelling to do. [contribution]
JELM	Commercial sponsor not really interested in myself as a student or my work, but rather with association with School and academic supervisors
GDAV	The previous industrial supervisor was mainly interested in furthering his own career, by exploiting the student. The new industrial supervisor, is not a supervisor and not interested in research. There has been very little support from academia.

ID	**Geography**
CFOS	The fact that the company is based in the US, and the university does not have access to technology such as video conferencing has been a real problem.
SPAR	Both sides of the collaboration work well, the only negative point from my point of view is that one needs to decide where to spend most of ones time, so that it isn't wasted constantly travelling, picking up the thread. This can lead to losing contact with one department or another and great effort must be made to stop this from happening as the participation of

	both sides is needed.

ID	**Other factors**
FWHI	Please note... (answer to Q40) *[relationship worsened]* is solely due to the change in individuals at the industrial partner
GAND	I have a sense that politics sometimes plays too large a role at the expense of knowledge generation.
GDAV	On the whole I have not enjoyed the experience. The project was very badly set out in the first place and got a lot worse before it improved slightly. The project has only got this far due to the determination of the Eng D Student.
SKIR	There is also the question of the company expecting the student to do a significant amount of work for them which is not related to the project and this often interfere with the said project.
RDAY	Too many times meetings have the feel of 'wouldn't it be nice if we could...' with no real attempt or possibility for this to happen
SKOM	The industrial side had give misleading information to the academic side about the site, which caused a lot of problems and delays to the progress of my research.
SDEN	In my opinion in this case it has lead to academia taking on a project that it didn't really have the facilities for...destroyed true research groups as everyone is working on an individual project and there is a limit to how much data can be shared.
KARF	Doing research in an industrial environment taught me that things will never go as planned, I have to always calculate some margin for error, uncertainties, red tape or pure unwillingness to help (from the industry's side)
KTAY	Once set up there seems to be little interest from the [RC] on the progress of the project. The industrial partner is unsure of exactly what they are supposed to contribute, especially with regard to directing the research.
NBRO	the relationship is always changing. not sure if i have given a proper reflection of this research as each project has specific issues that i don't feel are reflected in my answers/these questions
TMOR	There would appear to be more to gain from the scheme for the industrial sponsor in terms of an on-site resource having direct working experience. The benefit to the academic partner at this stage of the project (approx 6 months in) would seem to be purely funding with possible publicity benefits.
LGRA	Probably works better if one or both partners are not financially restricted... problems with projects where one partner takes control, rather than steering the project at a pace suitable for both, but generally collaborations have the potential to give industry cheap R&D/technical data required, while keeping researchers in universities that are increasingly struggling to find research funding.
APUG	The CASE funding is very slow to find its way from [IND] to the university.
HBEC	...much more pressure on a collaborative PhD student and it is easy to go off course with your own work because of pressures from collaborators. [
JFOC	I have to notify the partner and let them clear every document (e.g. for conferences) which is fair enough as it is part of the agreement, and it makes me work to schedules, although it can sometimes be tiresome when the document is sent back and forth until everyone in the clearing process is happy.

ID	**Good features of collaborative project**
APRO	Provides both practical experience and insights into a non-academic organisation, a useful way to make contacts and helps bring a new perspective into the academic work
MKIN	Provides a useful, speedy outlet for information generated, and also helps to improve the targeting of the project based on real industry/ grower experience.
APER	it is fundamentally good. there is a great deal to be gained particularly in terms of experience for the student. financially it is invaluable for academic research and on a personal level.
IPHI	I think the case studentship gives valuable experience to the PhD student...
YDUC	I think that it is a very valuable experience for the student as I found research in industry different to academic research. Also helped with career ideas. Highly recommend for the student. Industry has also allowed me to do experiments that we could not fund at the university.
RPAT	On the whole, projects with industrial collaborations produce students who are more employable, and who are aware of the benefits/pitfalls of careers in industry and academia.

FPIK	A beneficial scheme for PhD students - surely the future because it makes research relevant.
EINN	I think that it is an important collaboration as many academics are too steeped in an academic life and their research is not relevant to the outside world.
AFOR	I find that industry-academic collaboration is invaluable... working alongside an industry company gives direction and motivation... money into myself and my project it motivates me to work hard as I feel that I have to give quality work back to them, ensuring that high quality results are obtained or at least problems are encountered and tried to be overcome.
CKIL	The system is working very well in my case; the industry and academia (and myself) parties are getting what they want out of the collaboration.
CNAG	It is a very good idea and provided that a thorough initial plan is agreed upon, it can be beneficial to both sides as well as the student.
JHEI	It does seem to be a win-win situation, but this undoubtedly because of experienced academic staff & enthusiastic industrial staff, both of whom take great care of me!!
CSMI	It's a good thing - there are far too many PhD projects that are worthless postgraduate exercises. Encourages British nationals into the post grad area...
HNOB	In my case it was good to have a choice of bases because I could move from a small base to a large base with much more room and facilities to accommodate me and my work.
TBUT	Generally I have been very pleased and both partners have been exceptionally accommodating.
EWAL	Would suggest taking up CASE sponsored research to anyone
MHAR	Very useful for both parties
NON3	Very worthwhile, educational and useful.
ASIM	Good idea, should be encouraged
SWIL	Anyone who is thinking of working in industry would benefit from such collaboration
MBOW	There should be more of it, it seems to benefit both parties.
HTEW	I am very comfortable so far with both the collaboration

ID	**Benefit v disadvantages**
HBEC	The benefits (in terms of being close to centre of policy field, access to events, networking, future publication of my thesis, career benefits) outweigh the disadvantages (isolation from other PhD students, dealing with unrealistic expectations from industrial collaborator)...
JFOC	My experience has been personally tainted by the financial collapse of one of the partners... I still regard the CASE type collaboration to be very useful. It still gives an advantage over not having any external body to provide research orientated advice and it feels good to be working on something that someone will definitely use... All in all it is a good opportunity.
JNOS	The most useful experience it has provided me with is more to do with dealing with difficult people and difficult situations, which is a good skill but a disappointment as I hoped it would be more constructive as a research training and support facility.
RPOR	There are times when I thoroughly enjoy the project. At other times it is very frustrating.
BLOD	It was tough to begin with but improved as the four years went on.

ID	**Suggestions (related to Qu. 42 below)**
JASK	a little uncertain about what is expected... Would be very useful to involve the student as much as possible in outlining the project and to set clear guidelines and objectives at least for the first year to provide focus and increase student confidence in the project.
JCUT	Before starting the project both parties need to have a good idea of what the major goals are and what both parties are going to bring to the table - in my experience this has been very flakey
MMCK	both sides must be enthusiastic about the project - especially the industrial side as they commissioned the work
PSMI	It is essential that everyone is kept in the loop. It is easy for one person to fall out of contact and therefore not be able to contribute effectively. This is primarily the job of the Research Engineer.
RHIC	Universities should have a set protocol in place for students like me who are always based at the CASE institution, to provide us with support and help when necessary and not make out lives more difficult than they need to be because of red tape.
MRAY	Train research contract departments within universities to understand the needs of industry

	and also for these same departments to read the guidelines on industry/academia collaborations laid down in the [RC] handbook!
SMAG	Industry should be supporting Universities more, there is not enough applied research. doctorate students should get as near as possible a work environment to enhance future job opportunities
KCOU	Perhaps the agreement for extended overseas research could have been honoured
IPHI	...the student must be aware of the project specifications as it may be more restrictive than academia
TKIR	It is vital that both parties agree how the research is to progress... The student very much needs to take charge, in a way very different from a PhD.
JNOS	I think given the right environment and input from personnel, it can offer an excellent opportunity...

Qu. 42: "Have you any suggestions to help improve collaborative research?"

ID	**Prior collaborative experience**
ABOW	I think it helps if the industrial and academic parties have worked together before...
VHAN	The fact that the two supervisors have worked well together before has really benefited me.
SMCC	It helped that my supervisors already had a research relationship before the project started.
DBAL	There are very well established links between the *[uni & gov res centre]* ... and a long history of CASE supported students with joint supervision. I consider this to be very useful...

ID	**Communication/contact**
CWAR	More communication
JOWE	try and include the industrial partner on a more informal basis and open up pathways of communication so everyone is informed at all stages of the project.
CJOH	regular meetings and good communication of expectations and deliverables are essential...
SHAD	more face to face meetings with industrial supervisor would be good
MKIN	Ensure that the academic and industrial supervisors have good contact with each other as well as the student
NHARR	More meetings between collaborative partners would be helpful
EATT	Lots of industrial contact as well as academic.
ASIM	Better communication
CNEW	Perhaps more contact and communication...
RHOP	need to have regular meeting with industrial supervisor.
JFOC	Be very vocal when you need to be, especially when you have an idea of what's going on research wise... at the same time take on board what is being said to you, and respect their views. Always be prepared for what may be brought up at meetings, with regard to direction of research. There is nothing worse than a student having no ideas concerning the direction of their research.
JNOS	I have tried continually throughout the project and now with no supervisor in place, there is no communication. My own supervisors feel that there is little point in continually chasing it and I agree

ID	**Clarity re role/expectations**
HBEC	Could be clearer with industrial collaborators exactly what a PhD involves and what it can and can't achieve
NBRO	make clear guidelines at the beginning so that each party knows what to expect, what they need to do
SPRA	More clearly defined role and expectations of supervisors...
WBEN	It needs to be made very clear at the outset to the partner what their role is to be and what the expected outcomes are & the academic purpose of the PhD
ANEW	Better definition of roles and responsibilities. Clarity of expectations for academics (ie made aware of the probable differences between EngD and PhD progress)

SYEO	make sure that industrial sponsors fully appreciate how much time is taken by the MSc stage, and research. Inform them that EngDs are not about having a person do project work for less than they charge clients for.
SKIR	The sponsor need to understand fully what is required for the student to reach a doctoral level, and the student must be the most important consideration within the equation. Students should not be expected to undertake tasks for the company which do not affect or relate to the project.
GDAV	...if the sponsoring company has not had an Eng D student previously then they should be made aware that this is research.
JASK	Also for all parties to be as transparent as possible with regard to issues such as intellectual property so that full collaboration can be achieved.

ID	**Mutual understanding**
LWAR	Partners need a good understanding of research project, agreed aims ...
CJOH	...both sides must understand the others motives, desires and constraints
TKIR	Ensure that both sides understand what the goals are. In particular, the Academic supervisor needs to ensure that the project is novel work: the Industrial partner will ask for research into areas they know nothing about, but the problems may already have been solved.

ID	**Mutual interests/ Enthusiasm**
FPIK	Make sure both sets of supervisors are enthusiastic. I have known Case studentships where this isn't the case and there have been significant problems.
PSMI	Make sure that there are mutual interests between the academic and the company. If either party has nothing to gain, they will become less involved over time

ID	**Equality**
CSWA	Ensure that the 'tripartite' relationship between all parties is equal and that the PhD student is not simply a 'lackey' for industry needs.
KARF	Yes. Regulate and monitor the industry so researchers do not become or treated like a commodity for the industrial partner. Instead, it should be an equal relationship based in mutual understanding and respect of each other's needs. My experience, it has to be noted, is a negative one, simply because the individual I am supposed to work with is anything but helpful... Instead of helping, he continuously was asking for reports and stuff in order to strengthen his position in the organisation. Now this is BAD!
MHAR	Equal footing need to be applied for both parties for a close collaboration
RQUI	Industrial needs may be better served if they have more say in the overall management of the projects and students rather than just having a problem and saying "go away and solve". They after all, are the experts in their particular field. Unfortunately, the way CASE studentships are set up at present, industry isn't allowed the freedom to have students working for them directly, which may prove to be a stumbling block for all parties.
GDAV	...Academia should play an equal part in the project and should not simply agree to industry's demands, the qualification sought is an academic one and therefore they should play a larger, at least equal, role. Students should be supported far more and there should be far more feedback from academia

ID	**More industrial input/leadership**
CNEW	*[more]* ...input from the industrial supervisors
MMCK	industry must show more leadership when defining goals and outcomes of the project rather than just saying to the student: 'let's see what you come up with'
CWIL	Make sure the industrial collaborates uphold their responsibilities. Even if areas of interest change.
NHUT	There has to be motivation on the part of the employee at the industrial partner to push the process forward and ensure that the company fully benefits from their investment.
JFOC	...From the industrial side, I think set goals / targets to aim for...
PGOS	More involvement of operational site staff

ID	**Planning/agreement (at outset)**
JMOR	A clear and concise project proposal with actual academic and industrial benefits would have been helpful to begin with.
CWAR	...good statement of objectives before the start and a back-up plan in case things don't work to plan e.g. experiments fail.
ABOW	... it helps if the two parties agree on what they are expecting from the project and how it is to be managed before the work is started.
SELV	Project structure and aims need to stated and agreed very early on in the study and the differing time scales need be more explicit at the outset.
SKOM	...a lot more planning should be done before submitting the research design to the sponsor...
OGOO	A definite plan or timetable of work would have been helpful
VBOD	better defined timescales for accomplishing project's steps
SWIL	Time management is very important.
LBRA	The most pressing need appears to be for stated shared goals where possible and a clear timetable of work to be completed to keep all requirements fulfilled and all parties informed and aware of progress and difficulties regarding the research
RMCG	Must agree to a research program to be carried out at university.
CHIL	That there are standardised procedures for when supervisors leave the industry so that the student doesn't end up without a proper port of call within the industry that is working on the project too
LYOU	Formal agreements should be arranged at the start of the collaboration to protect IPR and interests of all parties should any commercially relevant research be done during the course of the programme
RCOO	More preliminary work before a student is taken on and then there must be close contact and clear agreement of future objectives.
DCAR	More interaction between industrial and academic supervisors at the beginning.
GDAV	The project should be set up properly....
MFEA	Better defined resources & research need at project inception
TJOY	After an initial period of study, say 6-12 months, I would suggest a review which specifically addresses the scope of the project to include such things as - What can practically be achieved in the time? Does the project warrant further researchers/MSc group projects? Do the Industrial & Academic supervisors believe they can offer the necessary levels of support, or should they bring in additional assistance to progress the project satisfactorily?

ID	**Flexibility**
NJEN	For my project, the initial project brief was very detailed and specific. This has led to an element of inflexibility in the project, especially relating to the use of specific research methods. As a result, I have sometimes found myself adapting the focus of enquiry to the methods rather than vice-versa. In hindsight, I would have preferred to lay out my project proposal as part of the interview procedure.
NON1	Ensuring there is some flexibility in supervisors on the industrial side. As projects progress they may become more focused on specific things which may mean the original supervisor is less interested or a more natural supervisor can be identified.
JFOC	Be flexible, sometimes you may have to go places at short notice for indiscriminate lengths of time, although it may fell like you are being hard done by, the advantage will more than likely be yours through the contacts you make or the experience gained. This flexibility will also endear you to those who can help you.
LWAR	supportive approach to student as well as being able to allow the student to develop the project independently

ID	**Industrial placement**
RHOP	...set up organised schemes to work in industry. I would have benefited greatly from spending time in their labs during the course of my PhD, or even fresh input into a problem. Industry has been no help at all.
KMCL	I spent a block of 8 months with my collaborative partner, aiding them with research and carrying out my own research. At times I was used very much as a local government officer by my industrial supervisor, and in many respects the periods when she has been on maternity leave have allowed me to pursue my academic interests. I think that the use of the

	industrial time should be thought carefully about before the project is started. As although my time at the authority has provided great insight into their methods of working, I have spent much of that time working for them, rather than on my work.
PALL	Perhaps with a view to the placements, a short one should take place at the start of the Ph.D, in which an insight into the industrial partner is gained and what their opinions are the desired outcome of the research. Then have a longer placement at the end of the PH.D (perhaps after submitting but before the viva) in which you try to apply the results of your research as they initial indicated. Obviously this would only be successful if good contact was maintained with the industrial sponsor throughout the project to ensure you are still heading towards the main objective.
JFOC	An induction period (after the settling in period at the host institution) would help ease you into the company work style and help make contacts easier.
PPAL	May be more beneficial to spend time in 'blocks' (e.g. 6 weeks) industrial institution, rather than in small periods (e.g. once a week). This, however, depends on the nature of the project and the work to be done at the time.
RING	It would have been good to have met with the industrial collaborators early in my PhD (within a few weeks of starting) to discuss how they intended to help me and what they wanted me to do for them.
ITRO	Spend as much time with CASE partner as possible
PBRI	Would be helpful to spend more time in Industry, as 3 months is a short time to experience industrial life and gain and insight into the workings and politics of a Pharmaceutical company.
DDOU	The student should be made to feel that they are a part of whichever institute they do not spend much time at, in addition to the one where they are normally based i.e. the chance to spend time at staff conferences and meetings, to see how the institute operates, so that the collaboration is not just in name only
DSHO	I would definitely make it a requirement that the student go and work in house for part of the project with the industrial sponsor
TNON	integrate students better in company (e.g. share options, bonus payments, information access,..)

ID	**Trust**
SKOM	The collaborative partner should be told honestly what the academic side wants to achieve, because lies will be found out later on and the student then gets the blame.
IADE	Researchers should be trusted and be given more room to work at his/her pace and should not be under constant time pressure and surveillance. The key issue is give him the time to think and reflect on his work.

ID	**More time/priority**
RMCG	This program should take priority over all other work.
RDAY	More time devoted to it

ID	**Geography/location**
DHOW	I think it helps regarding organising meetings between academia and industry if the two locations are close together.
GDAV	...The academic supervisor should be prepared to travel to the sponsoring company and should have done this prior to the student. One visit in three years of research is not acceptable. If the academic supervisor is not prepared to travel to the sponsoring company, because of distance then he should seriously consider the fact the EngD student has to do the journey far more often...

ID	**Funding/investment**
AONI	The minimum contributions of Industrial collaborators towards CASE awards should be increased to enhance all form of research on projects.
MLIE	How about increasing the length of funding by 6 months or more - as it is like two jobs going on at the same time
JCUT	rather than just sponsoring one random PhD student to work independently, the quality of research would benefit greatly from more core investment and the establishment of a research group that is highly specialised and devoted to one line of research. This would facilitate a much higher level of research. It requires a more and better defined investment

	from the CASE sponsor and more carefully planned research on behalf of the academic.

ID	**Right people**
CSMI	Needs an academic supervisor that is a bit of a sales/marketing machine to extract the best from the industrial side.
JHEI	Make sure you have the right staff!
NHUS	Try to match the student with a employee from a simpler educational background so that they understand what's involved with the research.

ID	**Not too many supervisors**
SPRA	...not too many of them *[supervisors]*
BDEC	Too many supervisors (2 in industry and 2 in academic). Reduce this number and will work faster.

ID	**External bodies**
LGRA	Need more collaborative agencies, matching industrial research needs to academic research facilities (such as Crystal Faraday Partnership etc). Funded collaborative projects should benefit all 4 parties, cheap but specialised labour for industry, cost free projects for universities and better bursaries for students while satisfying criteria of funding body.
RPOR	If done properly, it is a good idea - if not, then it is very frustrating for the student. In this case it is also frustrating for the industrial partner too. Some departments are not well adjusted to industrial research. I feel the only reason that this project was given the go ahead was because *[uni dept]* need more CASE studentships otherwise NERC may have cut grants in the future. I understand why NERC would like to see 30% of its projects CASE funded but it does let poorly planned projects go ahead instead of better planned, non CASE projects. It would be good if this could be addressed.
RPAT	The EngD manager role should be supported and competent people should be employed for the position. It would be good for the company to know that such a person exists, and the EngD manager should look after the interests of the student, examinations, thesis submission etc., so the academic supervisor can do less "housekeeping" and more research.

ID	**Other**
GAND	Keep the politics to an absolute minimum!]
TMAR	Leave it alone. Reduce paperwork and assessment.
MRIM	Tricky question. Problems will vary according to CASE but I can't help but feel that by their very nature there will always be room for some friction between industrial/partner and academic perspectives.
NHUS	...industrial supervisor should see some potential benefits for their *[student]* career advancements as this will maintain their interest
ISHA	Bring our demonstrable network security to the point where industrial partners would be happy for us to link our networks over even the most basic of connections. Currently there is a great deal of mistrust concerning most universities' IT security which precludes allowing such connections through a company's firewall. The impact on IT-based collaborative research would be immense if we could connect in this way.

ID	**More collaboration**
SSHE	I think more collaboration would improve the standing of academic research and make students feel more a part of the real world.
HCOL2	Should be more projects of this nature
DVIC	Have more of them CASE awards are a great way to fund PhD research.
AFOR	I think that there should be more CASE awards and that every student should have the opportunity to work with industrial partners.
EINN	More collaborations

ID	**Share experiences**
RCUR	The "feedback forum" is also useful as the researchers get a chance to raise any issues with the board without upsetting their own supervisors...

NON1	...Also some degree of collaboration between CASE students maybe beneficial in terms of sharing experiences

APPENDIX 5H: Questionnaire Survey Results – Additional tables (see Chapter 5.3)

Table 1: Industry's motivations

Industry motivation	Mode	5 'very true'	4	3	2	1 'not true at all'
To extend their knowledge base	5	**45.6%**	33.9%	12.2%	4.6%	3.7%
To have access to university facilities	2	13.9%	16.5%	16.2%	**27.2%**	26.2%
To have access to students	3	13.2%	22.6%	**24.7%**	23.0%	16.4%
To boost their sales/income	1	9.3%	15.7%	14.6%	19.3%	**41.1%**
To avoid in-house investment in long-term/riskier projects	1	9.1%	24.5%	16.6%	20.8%	**29.1%**
To have immediate problem solving	3	6.6%	17.6%	**26.2%**	25.2%	24.3%
To raise their profile within society	4	14.9%	**25.0%**	22.2%	19.1%	18.8%
To obtain prestige in marketplace	2	10.8%	19.0%	23.8%	**24.2%**	22.3%

Table 2: Relating industry's benefits to motivations

Industry motivation	Related benefit (codes)	Rank (of 18 categories)	% of students cited benefit
Extend knowledge base	ACEXKNOW	1	39.9%
Access university facilities	ACRESFAC	7	18.7%
Access students	ACCESTUD	4	24.4%
Boost sales/income	INDFUTUR	12	4.9%
Avoid in-house investment	CHEAPRES	2	29%
Immediate problem solving	PROBSOLV	14	3.2%
Raise profile within society	PRESTIGE	5	22.7%
Obtain prestige in marketplace	*(as above)*	-	-

(Benefit codes – see category list in Appendix 6C for definitions)

Table 3: Academic's motivations

Academic motivation	Mode	5 'very true'	4	3	2	1 'not true at all'
To generate income	5	**36.8%**	29.5%	17.5%	9.5%	6.7%
To find & work on real/industry's leading edge problems	5	**36.1%**	34.0%	16.2%	10.0%	3.7%
To develop individual reputations	4	18.6%	**34.6%**	24.3%	17.9%	4.7%
To see research being applied	4	29.5%	**43.5%**	17.7%	5.9%	3.4%
To have an impact on society	4	18.3%	**32.2%**	28.8%	14.2%	6.4%
To expose students to real world problems	4	25.6%	**38.5%**	23.0%	11.0%	1.9%
To improve employment opportunities for students	4	26.6%	**40.9%**	18.8%	11.3%	2.5%
To have access to industry facilities	4	24.6%	**31.5%**	17.4%	14.5%	12.0%

Table 4: Relating academic's benefits to motivations

Academic motivation	Related benefit	Rank (of 19 benefits)	% of students cited benefit
Generate income	MONEY	1	50.9%
Find/work on real problems	LINKCONT	2	41.4%
Develop individual reputations	PRESTIGE	4	29.6%
See research being applied	RESAPPLC	5	18.7%
Have impact on society	-	-	-
Expose students to real problems	STUDTRNG	13	3.4%
Student employment opportunities	STUDEMPL	11	3.7%
Access industry facilities	ACRESFAC	3	34.2%

(Benefit codes – see category list in Appendix 6C for definitions)

Table 5: Comments from students related to distance

Student ID	Comment
ODOU	My industrial collaborator is a long distance from the university... I'm not sure how much time I will actually spend there, probably very little.
RPAT	It is more difficult for students projects whose sponsors are based abroad to spend time at their companies, as no extra funding is allowed for travel etc...
GDAV	...Distance has been a huge issue as neither supervisor is prepared to travel... The academic supervisor should be prepared to travel to the sponsoring company... One visit in three years of research is not acceptable... should seriously consider the fact the engd student has to do the journey far more often...
CFOS	The fact that the company is based in the US, and the university does not have access to technology such as video conferencing has been a real problem.
RHIC	Because I'm based at the other end of the country from my university I have problems when I have to return for meetings, courses etc. and the university makes little effort to help me...
DHOW	I think it helps regarding organising meetings between academia and industry if the two locations are close together.

Table 6: Comparing the 'success' means by compatibility of supervisors' backgrounds

Compatibility of supervisors' disciplinary backgrounds		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
not at all compatible	Mean	3.33	2.56	3.22	9.11
	N	9	9	9	9
	SD	1.323	1.424	1.394	2.848
2	Mean	3.04	2.70	3.13	8.87
	N	23	23	23	23
	SD	1.261	.876	.815	1.914
3	Mean	3.46	3.14	3.54	10.14
	N	59	59	59	59
	SD	1.088	.991	.857	2.300
4	Mean	3.91	3.46	3.81	11.18
	N	111	111	111	111
	SD	.837	.829	.804	1.964
very compatible	Mean	4.09	3.69	3.90	11.68
	N	120	119	119	119
	SD	.898	.937	.817	2.213

(N = no. of cases; SD = standard deviation)

Table 7: Comparing percentage encountered personnel changes by size of company

Size (main) industrial sponsor	*Personnel changes in coordinaton group?* Yes	no
small	27.8%	72.2%
medium	28.6%	71.4%
large	28.6%	71.4%

Table 8: Comparing percentage encountered personnel changes by whether the partners have worked together before or not

Partners worked before project?	*Personnel changes in coordinaton group?* yes	no
yes	27.2%	72.8%
no	32.0%	68.0%

Table 9: Personnel changes by year of project

Year of Project		Personnel change - at what stage of project happened? (year) 1st	2nd	3rd	4th	Other
2nd	Count	17	9			1
	%	63.0%	33.3%			3.7%
3rd	Count	16	24	7		3
	%	32.0%	48.0%	14.0%		6.0%
4th	Count	4	4	2	2	
	%	33.3%	33.3%	16.7%	16.7%	
part-time	Count			1		
	%			100.0%		
Total	Count	37	37	10	2	4
	%	41.1%	41.1%	11.1%	2.2%	4.4%

Table 10: Comparing 'success' means by year of project - CASE students only

Year of Project		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
1st	Mean	3.61	3.22	3.60	10.43
	N	59	58	58	58
	SD	1.000	.937	.748	2.264
2nd	Mean	3.89	3.42	3.84	11.14
	N	98	98	98	98
	SD	.994	.896	.782	2.091
3rd	Mean	3.88	3.41	3.85	11.14
	N	115	115	115	115
	SD	1.019	1.025	.840	2.347

(N = no. of cases; SD = standard deviation)

Table 11: Comparing satisfaction with project's progress by year of project – CASE only

Year of Project	*How satisfied with project's progress?* 1 'not at all satisfied'	*2*	*3*	*4*	*5 'very satisfied'*
1st		13.8%	34.5%	41.4%	10.3%
2nd		12.5%	37.5%	29.2%	20.8%
3rd	.9%	11.2%	24.1%	44.0%	19.8%

Table 12: Comparing 'success' means by year of project – EngD students only

Year of Project		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
1st	Mean	3.40	3.50	3,00	9.90
	N	10	10	10	10
	SD	.843	.972	.943	2.378
2nd	Mean	3.57	3.79	3.21	10.57
	N	14	14	14	14
	SD	1.222	1.051	1.122	2.848
3rd	Mean	3.76	3.24	3.76	10.76
	N	17	17	17	17
	SD	1.251	1.393	1.033	3.133
4th	Mean	3.61	3.43	3.57	10.61
	N	23	23	23	23
	SD	.839	.728	.788	1.777

(N = no. of cases; SD = standard deviation)

Table 13: Comparing satisfaction with project's progress by year of project – EngD only

Year of Project	*How satisfied with project's progress?*				
	1 'not at all satisfied'	*2*	*3*	*4*	*5 'very satisfied'*
1st		20.0%	70.0%	10.0%	
2nd	14.3%	14.3%	21.4%	42.9%	7.1%
3rd	6.3%	6.3%	31.3%	50.0%	6.3%
4th	4.8%	14.3%	14.3%	52.4%	14.3%

Table 14: Comparing the 'success' means by industrial supervisor's enthusiasm

How enthusiastic is industrial supervisor about project?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
not at all enthused	Mean	2.57	2.07	3.00	7.64
	N	14	14	14	14
	SD	1.222	1.207	1.177	2.790
2	Mean	2.90	2.48	3.45	8.83
	N	29	29	29	29
	SD	1.205	.986	.827	2.331
3	Mean	3.35	3.00	3.42	9.77
	N	48	48	48	48
	SD	.887	.899	.821	1.836
4	Mean	3.71	3.31	3.70	10.72
	N	89	89	89	89
	SD	.968	.820	.817	2.067
very enthused	Mean	4.27	3.88	3.96	12.11
	N	148	148	148	148
	SD	.734	.755	.799	1.819

(N = no. of cases; SD = standard deviation)

Table 15: Comparing the 'success' means by academic supervisor's enthusiasm

How enthusiastic is academic supervisor about project?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
not at all enthused	Mean	3.67	2.67	2.33	8.67
	N	3	3	3	3
	SD	.577	1.528	.577	2.309
2	Mean	3.09	2.91	2.73	8.73
	N	11	11	11	11
	SD	1.300	.944	.786	2.284
3	Mean	3.13	3.23	3.19	9.55
	N	31	31	31	31
	SD	1.284	1.117	.946	2.706
4	Mean	3.59	3.19	3.51	10.29
	N	104	104	104	104
	SD	.899	.871	.737	2.003
very enthused	Mean	4.03	3.54	4.00	11.57
	N	191	190	190	190
	SD	.956	.995	.783	2.202

(N = no. of cases; SD = standard deviation)

Table 16: Comparing the 'success' means by industrial supervisor's understanding

Extent industrial supervisor understands work		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
not at all	Mean	2.92	1.92	3.08	7.92
	N	13	13	13	13
	SD	1.44	1.12	1.04	2.72
2	Mean	3.03	2.50	3.30	8.83
	N	40	40	40	40
	SD	0.95	0.85	0.91	2.02
3	Mean	3.44	3.16	3.48	10.08
	N	63	63	63	63
	SD	1.15	0.85	0.80	2.00
4	Mean	3.93	3.50	3.87	11.29
	N	107	107	107	107
	SD	0.77	0.79	0.74	1.77
very well	Mean	4.23	3.94	3.96	12.13
	N	104	104	104	104
	SD	0.91	0.83	0.86	2.17

(N = no. of cases; SD = standard deviation)

Table 17: Comparing the 'success' means by academic supervisor's understanding

Extent academic supervisor understands work		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
2	Mean	3.17	3.25	2.67	9.08
	N	12	12	12	12
	SD	1.27	0.97	0.89	2.27
3	Mean	3.55	3.27	3.36	10.18
	N	33	33	33	33
	SD	1.12	0.98	0.90	2.57
4	Mean	3.70	3.13	3.52	10.34
	N	79	79	79	79
	SD	0.98	0.91	0.78	2.04
very well	Mean	3.90	3.50	3.94	11.34
	N	210	209	209	209
	SD	1.00	1.01	0.79	2.31

(N = no. of cases; SD = standard deviation)

Table 18: Comparing the 'extent project is characterised by good management' means by restrictiveness of project management

How restrictive is project management?	Mean	N	Std. Deviation
not at all restrictive	3.43	90	1.050
2	3.46	115	.949
3	3.59	88	.905
4	3.43	30	1.073
very restrictive	2.67	3	1.528

Table 19: Comparing the means for the extent project is characterised by good management by who manages the project

Who coordinates / manages relationship?	Mean	N	Std. Deviation
Industrial	3.05	21	1.024
Academic	3.44	167	1.044
Both	3.60	145	.861

Table 20: Comments from students related to prior collaborative experience

Stud. ID	Comment
ABOW	I was fortunate because my industrial and academic supervisors had worked together on a number of other research projects before... I think it helps if the industrial and academic parties have worked together before...
DEGA	I am lucky as the industrial and academic supervisors know each other very well and have worked together before. They therefore know what they might expect of each other in a professional capacity. I have felt very welcome since I started.
TKIR	I was lucky, my Industrial supervisor has supervised many PhDs, but other students have suffered by because they Industrial supervisor had no research experience and the Academic supervisor no Industrial experience.
KTAY	University and [IND] already had a long standing research agreement when I arrived, so it's been ideal.
VHAN	The fact that the two supervisors have worked well together before has really benefited me.
SMCC	It helped that my supervisors already had a research relationship before the project started.
DBAL	There are very well established links between *[Academic & Industry]* ... and a long history of CASE supported students with joint supervision. I consider this to be very useful...

Table 21: Comparing the success means by size of company within each sector (Research Council)

Research Council	Size industrial sponsor (main)	*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
EPSRC	small	3.20	3.20	3.27	9.67
	medium	4.25	3.75	3.88	11.88
	large	3.64	3.40	3.53	10.57
ESRC	small	3.57	2.71	3.57	9.86
	medium	3.59	3.00	3.41	10.00
	large	4.00	3.38	3.81	11.19
NERC	small	3.78	3.33	3.33	10.44
	medium	3.89	3.67	3.89	11.44
	large	4.02	3.71	4.02	11.75
PPARC	small	-	-	-	-
	medium	3.67	3.67	3.33	10.67
	large	3.85	3.54	3.77	11.15
BBSRC	small	3.78	2.67	3.89	10.33
	medium	4.00	3.36	3.73	11.09
	large	3.77	3.28	3.85	10.89

Table 22: Suggestions from students related to making industry more aware of their role in the project

Student ID	Comment
HBEC	Could be clearer with industrial collaborators exactly what a phd involves and what it can and can't achieve
SYEO	make sure that industrial sponsers fully appreciate how much time is taken by the MSc stage, and research. Inform them that EngD's are not about having a person do project work for less than they charge clients for.
SKIR	The sponsor need to understand fully what is required for the student to reach a doctoral level, and the student must be the most important consideration within the equation. Students should not be expected to undertake tasks for the company which do not affect or relate to the project.
GDAV	...if the sponsoring company has not had an Eng D student previously then they should be made aware that this is research.
KMCL	I spent a block of 8 months with my collaborative partner, aiding them with research and carrying out my own research. At times I was used very much as a local government officer by my industrial supervisor, and in many respects the periods when she has been on maternity leave have allowed me to pursue my academic interests. I think that the use of the industrial time should be thought carefully about before the project is started. As although my time at the authority has provided great insight into their methods of working, I have spent much of that time working for them, rather than on my work.

Table 23: Comments from students related to confidentiality or publishing issues

Student ID	Comments
MLAT	industrial partners may have issues with publishing of papers due to wanting to develop a product from my results.
JKEA	Any results to be published or presented must first go through the industrial partner and they can delay publication...
MBOT	Potentially, if there was a new discovery that would be beneficial to my industrial supervisor, I would be held back in publishing this.
NON3	Some work may end up being patentable, and hence there is a difficulty in publishing and reporting on it. On the academic side, we'd prefer to publish.
JANS	Publishing could be an issue, my industrial partner has to approve publications, if they don't approve publication can be delayed by up to a year (its in the contract)
RDAY	Knowing what we can publish and what must remain an industrial secret.
HTEW	Industrial sensitivity of some aspects of the project, confidentiality in reports etc.
RPEA	Some information in the project is of a confidential nature which does cause a degree of difficulty at times when reports need to be issued at university.
LGRA	Not a major problem, but due to sensitivity of some material industrial partner needs to OK everything prior to use
PALL	My research at [IND] is of a confidential nature, while my academic supervisor does not have the necessary clearance to see some of the results and data that i produce for [IND]. This means an abundance of time is spend switching between models trying to explain problems without actually showing too much detail.
EEDW	Work that was to be presented at a conference did not get through company intellectual property clearance in time. However the problem was overcome by removing any references to the company from the poster
JFOC	I have to notify the partner and let them clear every document (e.g for conferences) which is fair enough as it is part of the agreement, and it makes me work to schedules, although it can sometimes be tiresome when the document is sent back and forth until everyone in the clearing process is happy.

Table 24: Comparing the success means by if the student was asked to sign the collaboration agreement in force for their project or not

Collaboration agreement - asked to sign?		*Success of collaboration personally*	*Success of collaboration for industrial side*	*Success of collaboration for academic side*	*Overall success*
Yes	Mean	3.87	3.34	3.80	11.01
	N	94	94	94	94
	Std. Deviation	.964	1.022	.798	2.197
no	Mean	3.79	3.53	3.74	11.05
	N	19	19	19	19
	Std. Deviation	1.134	1.020	.933	2.415

[N = no. of cases; SD = standard deviation)

Table 25: Comparing the means for the extent the project is characterised by good management, good communication & mutual interest/need by age group

Age group	*Extent project characterised by good management*	*Extent project characterised by good communication*	*Extent project characterised by mutual interest/need*
21-25	3.52	3.63	3.87
26-30	3.36	3.51	3.66
31-35	3.19	3.26	3.48
36-40	3.43	3.64	4.00
41-45	3.88	4.50	3.75
46-50	3.00	4.50	4.00
51-55	4.00	4.50	5.00

Table 26: Comparing the 'importance' (mean) of email, phone & face-to-face for communicating with the industrial and academic supervisors by age group

Age group	*With industrial supervisor*			*With academic supervisor*		
	Email	*Phone*	*Face-to-face*	*Email*	*Phone*	*Face-to-face*
21-25	4.20	2.56	3.65	3.75	2.26	4.68
26-30	4.07	2.64	3.95	3.88	2.61	4.59
31-35	3.85	2.92	3.71	3.92	2.24	4.62
36-40	4.71	3.07	4.21	4.50	2.86	4.57
41-45	3.88	2.00	3.75	4.88	3.13	5.00
46-50	3.67	1.67	4.33	3.33	1.00	4.67
51-55	5.00	2.00	4.50	5.00	2.00	4.50

Table 27: CASE & EngD students' motivations for doing collaborative project
(only 5 most frequently mentioned motivations shown; definitions for categories shown in Appendix 6C)

CASE		**EngD**	
1.	MONEY (43%)	1.	INDEXPE (42.2%)
2.	INDEXPE (25.7%)	2.	RESAPPLC (35.9%)
	RESAPPLC (25.7%)	3.	SKLLTRNG (28.1%)
4.	CAREER (21.1 %	4.	MONEY (23.4%)
5.	CONTCOLL (19%)		CAREER (23.4 %)
			KNWEXBTH (23.4%)

Table 28: Benefits that CASE & EngD students gain from industrial side
(only 5 most frequently mentioned benefits shown; definitions for categories in Appendix 6C)

CASE		**EngD**	
1.	ACRESFAC (51.8%)	1.	INDEXPE (62.5%)
2.	INDEXPE (46.8%)	2.	CONTNETW (40.6%)
3.	SKLLTRNG (28.9%)	3.	SKLLTRNG (31.3%)
4.	CONTNETW (25.7%)	4.	ACKNWEXP (28.1%)
5.	MONEY (18.7%)	5.	RESAPPLC (17.2%)

Table 29: Benefits that CASE & EngD students gain from academic side
(only 5 most frequently mentioned benefits shown; definitions for categories in Appendix 6C)

CASE		**EngD**	
1.	SKLLTRNG (74.6%)	1.	SKLLTRNG (75%)
2.	ACAINPUT (33.5%)	2.	ACKNWEXP (51.6%)
3.	ACKNWEXP (30.3%)	3.	ACAINPUT (25%)
4.	CONTNETW (21.8%)	4.	ACRESFAC (18.8%)
5.	ACRESFAC (18.7%)		PRJMGMT (18.8%)

Table 30: Benefits that industrial side gain from CASE & EngD projects
(only 5 most frequently mentioned benefits shown; definitions for categories in Appendix 6C)

CASE		**EngD**	
1.	ACEXKNOW (41.9%)	1.	CHEAPRES (46.9%)
2.	LINKCONT (28.2%)	2.	ACCESTUD (34.4%)
3.	CHEAPRES (25%)	3.	ACEXKNOW (31.3%)
4.	PRESTIGE (24.6%)	4.	POTLEMPL (25%)
5.	ACCESTUD (22.2%)	5.	LINKCONT (21.9%)

Table 31: Benefits that academic side gain from CASE & EngD projects
(only 5 most frequently mentioned benefits shown; definitions for categories in Appendix 6C)

CASE		**EngD**	
1.	MONEY (52.8%)	1.	LINKCONT (50%)
2.	LINKCONT (39.4%)	2.	MONEY (42.2%)
3.	ACRESFAC (39.1%)	3.	PRESTIGE (35.9%)
4.	PRESTIGE (28.2%)	4.	ACEXKNOW (23.4%)
5.	RESAPPLC (18.3%)		FUTROPPO (23.4%)

Table 32: Variables related to supervisors: CASE versus EngD responses

Variable description	CASE (Mode/%)	EngD (Mode %)
Industrial supervisor's understanding	4	5
Academic supervisor's understanding	5	5
Industrial supervisors' enthusiasm	5	5
Academic supervisor's enthusiasm	5	5
Compatibility of supervisors' backgrounds	5	4
Differences between partners a problem	20.1%	29.7%
Partners worked before	58.1%	60.9%

Table 33: Variables related to supervisors: CASE versus EngD responses

Communication mode	With Industrial supervisor		With Academic supervisor	
	CASE (mean)	EngD (mean)	CASE (mean)	EngD (mean)
Email	4.18	4.02	3.79	4.15
Phone	2.51	2.97	2.24	3.00
Face-to-Face	3.68	4.18	4.74	4.28